Biological characteristics of Atlantic herring (*Clupea harengus harengus* L.) from Newfoundland's west coast for the 1965-2001 period

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BIOLOGICAL CHARACTERISTICS OF ATLANTIC HERRING (*Clupea harengus harengus* L.) FROM NEWFOUNDLAND'S WEST COAST FOR THE 1965-2001 PERIOD

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TABLE OF CONTENTS

LIST OF TABLES iv

LIST OF FIGURES v

LIST OF APPENDICES vii

ABSTRACT / RÉSUMÉ viii

INTRODUCTION 1

MATERIAL AND METHODS 1

Sampling of herring landings 1

Data presentation and analysis 1

RESULTS 2

CONCLUSION 4

ACKNOWLEDGEMENTS 4

REFERENCES 5

LIST OF TABLES

Table 1. Number of herring sampled by month in NAFO Division 4R for the 1965-2001 period (total and average by month and year are also presented) 6

Table 2. Number of herring sampled in NAFO Subdivision 3Pn and unit areas 4Ra, 4Rb, 4Rc, and 4Rd for the 1965-2001 period (total and average by year are also presented) 7

Table 3. Mean length (mm) at age for spring and fall spawning herring in NAFO Division 4R for different periods of time (data fitted according to the von Bertalanffy growth model) 8

LIST OF FIGURES

Figure 1. Map of the unit areas of NAFO Division 4R on the west coast of Newfoundland (Division 4R is indicated by the shaded area) 9

Figure 2. Landings (t) and number of herring sampled in NAFO Division 4R (A), grouped by month (B), and age (C) for the 1965-2001 period (age group 11+ represents all fish 11 years of age or over) 10

Figure 3. Number of herring sampled by year, unit area, and spawning group for the 1965-2001 period 11

Figure 4. Number of herring sampled by month, unit area, and spawning group for the 1965-2001 period 13

Figure 5. Mean length (mm) (A) and weight (g) (B) at age for spring and fall spawning herring sampled in NAFO Division 4R between 1965 and 2001 15

Figure 6. Mean length (mm) (A) and weight (g) (B) at age for spring spawning herring in NAFO Division 4R for different periods of time 16

Figure 7. Mean length (mm) (A) and weight (g) (B) at age for fall spawning herring in NAFO Division 4R for different periods of time 17

Figure 8. Weight-length relationships calculated for spring (A) and fall (B) spawning herring in NAFO Division 4R for different periods of time 18

Figure 9. Mean length (mm) at age by year-class for spring spawning herring sampled in NAFO Division 4R since 1965 (the largest year-classes that have dominated the fishery are also indicated) 19

Figure 10. Mean length (mm) at age by year-class for fall spawning herring sampled in NAFO Division 4R since 1965 (the largest year-classes that have dominated the fishery are also indicated) 21

Figure 11. Catch at age (%) of spring (A) and fall (B) spawning herring for the year-classes sampled in NAFO Division 4R since 1965 (strong year-classes are also shown; age group 11+ represents all fish 11 years of age or over) 23

Figure 12. Mean maturity percentages at age for spring (A) and fall (B) spawning herring sampled in NAFO Division 4R since 1965 and grouped by different periods of time 24

Figure 13. Mean daily values, standard deviations, and fitted values of the gonadosomatic index for spring spawning herring sampled in NAFO Division 4R since 1970 (data were fitted with a polynomial model except in 2000-2001 where their numbers were insufficient) 25

Figure 14. Mean daily values, standard deviations, and fitted values of the gonadosomatic index for fall spawning herring sampled in NAFO Division 4R since 1970 (data were fitted with a modified Weibull model) 27

Figure 15. Mean daily length (cm) values of spring spawning herring sampled in NAFO Division 4R since 1965 and grouped by different periods of time 29

Figure 16. Mean daily length (cm) values of fall spawning herring sampled in NAFO Division 4R since 1965 and grouped by different periods of time 31

Figure 17. Mean gonad weight (g) by length (mm) for spring (A) and fall (B) spawning herring sampled in NAFO Division 4R since 1970 33

LIST OF APPENDICES

Appendix 1. Weight-length relationships for spring and fall spawning herring of NAFO Division 4R for different periods of time 34

Appendix 2. Comparisons by period of time of the fitted weight-length relationships for spring and fall spawning herring in NAFO Division 4R 36

Appendix 3. Daily gonadosomatic index values (observed and fitted) for spring spawning herring in NAFO Division 4R for different periods of time 37

Appendix 4. Daily gonadosomatic index values (observed and fitted) for fall spawning herring in NAFO Division 4R for different periods of time 38

ABSTRACT

Grégoire, F., and L. Lefebvre. 2003. Biological characteristics of Atlantic herring (*Clupea harengus harengus* L.) from Newfoundland's west coast for the 1965-2001 period. Can. Ind. Rep. Fish. Aquat. Sci. 270: viii + 38 p.

Commercial herring landings on Newfoundland's west coast have been sampled regularly since the mid-1960s. An analysis of the collected samples indicates that the two spawning stocks have identical growth rates (length and weight). However, variations have been noted over the years. For example, although the 1980s were distinguished by more rapid herring growth, the dominant year-classes grew at a slower rate. In recent years, the two spawning stocks have reached sexual maturity at a younger age and spawning has occurred at a later date.

RÉSUMÉ

Grégoire, F., and L. Lefebvre. 2003. Biological characteristics of Atlantic herring (*Clupea harengus harengus* L.) from Newfoundland's west coast for the 1965-2001 period. Can. Ind. Rep. Fish. Aquat. Sci. 270: viii + 38 p.

Les débarquements commerciaux de hareng de la côte ouest de Terre-Neuve sont l'objet d'un échantillonnage régulier depuis le milieu des années 1960. L'analyse des échantillons recueillis indique que la croissance en longueur ou en poids des deux groupes reproducteurs est identique. Cependant, des variations ont été observées au cours des ans. On constate par exemple que les années 1980 se distinguent par une croissance plus rapide du hareng. Par contre, une croissance plus lente caractérise les classes d'âge dominantes. Au cours des dernières années, la maturité sexuelle des harengs des deux groupes reproducteurs a été atteinte à un plus jeune âge et la ponte s'est déroulée plus tardivement.

INTRODUCTION

Commercial herring (*Clupea harengus harengus* L.) landings on Newfoundland's west coast have been sampled regularly since the mid-1960s. Over the years, the biological data gathered have been analyzed and used to describe the demographic structure of herring populations in this part of the Gulf of St. Lawrence. In addition, some of the data were used for directly managing the species' stock and assessing its abundance.

The biological characteristics of herring are one of the main issues discussed at meetings with fishing industry representatives. Questions about age associated with herring of a certain size, weight corresponding to length, growth, gonad weight, and the presence of dominant year-classes are among those most frequently asked. To date, the answers to these fundamental questions have not been the subject of a publication specifically intended for the industry.

This report is intended to present the main biological characteristics of commercial herring landings to the pelagic fishing industry on Newfoundland's west coast. Because sampling now covers more than 30 years, the report also attempts to describe the evolution of certain biological parameters (e.g., length, weight, and maturity at age) over the same period.

MATERIAL AND METHODS

Sampling of herring landings

Commercial herring landings on Newfoundland's west coast are sampled in accordance with standard protocols (Lambert and Ménager, 1998), certain basic principles of which were first established in the early 1950s (International Commission for the Northwest Atlantic Fisheries, 1952). For example, in order to obtain a comprehensive, unbiased description of the population studied, one of these principles stipulates that commercial sampling must be conducted over the entire fishing season and must cover the main gear and landing ports.

For each herring landing sampled, sampling activities involved randomly collecting 250 fish that were measured to the nearest 0.5 cm. In addition, among the fish not measured, 55 herring were set aside and frozen for laboratory analysis to measure the following parameters: total length, total weight, sex, sexual maturity, gonad weight, and spawning group. Age was determined from the otoliths and the spawning group was determined by the degree of maturity of the gonads (McQuinn 1987, 1989). All of these variables were validated and incorporated into a data bank, which we used to describe the main biological characteristics of herring in this report.

Data presentation and analysis

The number of herring subjected to laboratory analysis is presented per year, month, unit area (Figure 1), age, and spawning group. The mean length, weight, and maturity at age (%) were

calculated for each spawning group and by decade in order to reveal possible trends. The relationships between total weight and length for the same period were described using exponential models. The growth of each year-class sampled since 1965 was described in terms of mean length at age, and their respective abundance was expressed as a percentage of the total catch at age. Mean length per sample and mean gonad weight by length were examined by year for each spawning group.

Somatic weight and gonad weight were used to calculate the gonadosomatic index (GSI) as follows:

$$(1) \quad GSI = \left[1 - \frac{\text{Somatic weight}}{\text{Somatic weight + Gonad weight}} \right] \times 100$$

The gonadosomatic index is used to measure gonad weight as compared to total body weight of the corresponding fish and to describe the spawning timeline. Daily gonadosomatic index averages were grouped by year and decade and then modelled using a polynomial model for spring spawners; the Weibell model (SigmaPlot 1997) was adjusted and used for fall spawners.

RESULTS

A total of 127,863 herring have been sampled and analyzed in the laboratory since 1965 (Table 1). The number of herring sampled per year gradually increased between 1965 and the mid-1980s and between 1990 and 1995. However, this number has been decreasing steadily since 1995. In most cases, sampling intensity is related to landing volume (Figure 2A). On average, close to 3,500 herring were sampled per year. May and November are the most important months (Figure 2B), and most of the herring sampled were either between 5 and 7 years of age or 11 years of age or older (Figure 2C).

Of all the herring sampled since 1965, just over half (69,043) were taken from unit areas 4Ra and 4Rb, where close to 1,000 herring have been harvested per year (Table 2). Close to 61% (75,038) of the herring sampled were spring spawners. In recent years, spring spawning herring have mainly been sampled in unit areas 4Rc and 4Rd in spring (Figures 3 and 4), compared with area 4Ra in summer and 4Rb in fall for fall spawners.

For the period under study, the mean lengths and weights at age were almost identical for the two spawning stocks (Figures 5A and 5B). However, variations were noted during different periods for both spawning stocks, with the highest mean lengths (Figures 6A and 7A) and weights (Figures 6B and 7B) at age recorded in the 1980s. Variations in the weight-length relationships were also observed between various periods (Figures 8A and 8B), with values varying from year

to year (Appendix 1). Until the late 1980s, the weight-to-length relationships were slightly greater among spring spawners (Appendix 2).

Differences were also noted in mean lengths at age between the various year-classes. In most cases, they were lower among dominant year-classes. This is true for the spring spawning year-classes of 1968, 1974, 1980, 1982, and 1987 (Figures 9 and 11A) compared with the fall spawning year-classes of 1979, 1988, and 1995 (Figures 10 and 11B).

There are also significant differences between the mean percentages of maturity at age for the various periods. In 2001, both spring and fall spawners reached maturity at a younger age than in the 1960s and 1970s (Figures 12A and 12B).

At the beginning of the spawning season, i.e., late April (day of the year 120), the gonadosomatic index for spring spawners is high, ranging from 15% to 20% (Figure 13). It then drops sharply to 5% in late June (day 180) and increases in early September (day 244), reaching values of around 15% in mid-December (day 350). The pattern of change in gonadosomatic index values is similar from year to year (Appendix 3). However, the maximum values reached may vary annually. In addition, as indicated by modelled values, a delay in spawning was noted in the 1990s compared with the 1970s and 1980s (Figure 13). Lastly, it is interesting to note a slowdown in gonad development in late October, i.e., as of day of the year 300, followed by a sharp surge in growth around day of the year 340.

The gonadosomatic index for fall spawners generally remains below 5% until early June (day 152) (Figure 14). It then rises sharply, reaching values of between 15% and 25% between July 15 (day 196) and September 15 (day 258). After that date, the index falls to values below 5% around the end of September (day 273). Maximum values may vary from year to year (Appendix 4). The pattern of seasonal changes is consistent, but spawning occurred later during the 1990s than in previous decades (Figure 14).

The daily mean length of herring sampled from both spawning stocks varied little over a fishing season (Figures 15 and 16). However, a certain reduction in size was noted as of November (day of the year 305). The mean gonad weight was under 10 g for herring smaller than 290 mm (Figures 17A and 17B). It increased gradually for herring measuring between 290 mm and 400 mm, without major variations in length. A linear relationship could be used to predict average gonad size based on length with a high degree of accuracy. However, for fish bigger than 400 mm, major differences were noted in gonad weight for herring of the same length.

CONCLUSION

In addition to answering fundamental questions asked regularly by the industry, this report has shed light on some specific aspects of herring biology. For example, changes in growth, maturity, and spawning dates noted over the study period clearly indicate that herring populations off Newfoundland's west coast are constantly changing. It would be interesting to study the possible factors or mechanisms underlying these changes.

Another interesting aspect of herring biology highlighted in this report concerns the slower growth of dominant year-classes. This phenomenon has also been noted in the dominant 1977 year-class of Pacific herring (*Clupea pallasii*) (Hay et al. 2000). Various theories related to environmental changes and/or relationships with other fish species (predation, competition) were offered to try to explain the occurrence of this year-class and the fact that adults in the year-class grew at a slower rate. The same hypotheses could be studied for the situation of herring off Newfoundland's west coast.

Biological data for herring found off Newfoundland's west coast could also be analyzed on a smaller spatial scale. On various occasions, it was said that the fall spawning herring stock caught in different areas could be distinguished by their shape or thickness (Scott Anderson, captain of a large purse seiner vessel, pers. comm.). Such observations could be used to develop new research projects, which could even be conducted with the industry.

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We would like to extend our deepest thanks to all of the samplers who at one time or another worked on Newfoundland's west coast, and especially Jerry Lavers for his extensive work over the years in gathering commercial samples. The accuracy of the data presented in this report is owed to the exceptional quality of Mr. Lavers' work. Thanks also goes to Sylvain Hurtubise, head of the MLI commercial sampling program, Diane Archambault, Marthe Bérubé and Laure Devine for reviewing this report.

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Table 1. Number of herring sampled by month in NAFO Division 4R for the 1965-2001 period (total and average by month and year are also presented).

YEAR	MONTH													
	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPT.	OCT.	NOV.	DEC.	TOTAL	AVERAGE
1965	0	0	0	0	0	0	0	0	0	0	100	465	565	87
1966	0	0	0	0	0	0	0	0	0	148	250	200	598	92
1967	100	0	0	46	199	100	0	0	50	356	100	445	1396	215
1968	76	0	50	250	0	0	0	0	0	24	250	100	750	115
1969	0	50	0	0	0	0	0	100	0	0	50	496	696	107
1970	0	0	0	200	0	50	100	50	0	198	150	350	1098	169
1971	0	0	0	150	300	600	0	0	250	0	650	100	2050	315
1972	147	0	0	0	400	0	922	150	400	300	1976	0	4295	661
1973	450	0	0	696	286	0	538	0	0	200	1586	500	4256	655
1974	0	0	0	200	649	100	30	645	0	0	50	650	2324	358
1975	0	0	0	50	600	150	347	0	0	0	0	0	1147	176
1976	0	0	0	740	648	100	350	0	0	0	300	300	2438	375
1977	0	0	0	1140	995	340	535	150	650	500	250	150	4710	725
1978	94	0	0	815	227	199	900	100	0	0	1124	450	3909	601
1979	0	0	0	2096	296	0	350	500	199	250	350	150	4191	645
1980	0	0	0	2346	498	600	549	200	350	100	649	1085	6377	981
1981	0	0	0	2844	409	200	400	300	0	924	192	97	5366	826
1982	0	0	0	404	739	0	150	0	100	297	389	0	2079	320
1983	0	0	0	393	344	0	53	219	249	518	1638	333	3747	576
1984	55	0	0	932	404	151	50	1182	445	1333	1247	887	6686	1029
1985	0	0	0	0	1947	385	0	956	293	950	2050	650	7231	1112
1986	0	0	0	450	1949	0	199	792	100	1047	1138	100	5775	888
1987	0	0	0	549	1211	278	0	1039	400	592	496	290	4855	747
1988	0	0	0	682	1883	478	444	742	392	345	748	500	6214	956
1989	0	0	0	50	1578	627	178	328	277	544	548	300	4430	682
1990	0	0	0	0	920	344	335	438	245	200	550	250	3282	505
1991	0	0	0	0	745	150	350	198	147	250	395	150	2385	367
1992	0	0	0	0	644	535	200	98	150	99	1230	0	2956	455
1993	0	0	0	198	1231	271	200	350	350	250	455	0	3305	508
1994	0	0	0	0	1150	810	435	1490	858	650	350	0	5743	884
1995	0	0	0	50	1298	927	471	876	610	410	469	310	5421	834
1996	0	0	0	100	1075	669	250	647	855	407	400	200	4603	708
1997	0	0	0	50	1248	530	150	480	604	400	200	0	3662	563
1998	0	0	0	150	701	232	100	350	550	150	200	50	2483	382
1999	0	0	0	149	927	447	50	250	444	250	50	0	2567	395
2000	0	0	0	50	1053	375	50	300	150	200	500	0	2678	412
2001	0	0	0	50	582	313	600	50	0	0	0	0	1595	245
TOTAL	922	50	50	15830	27136	9961	9286	12980	9118	11892	21080	9558	127863	
AVERAGE	25	1	1	428	733	269	251	351	246	321	570	258	3456	

Table 2. Number of herring sampled in NAFO Subdivision 3Pn and unit areas 4Ra, 4Rb, 4Rc, and 4Rd for the 1965-2001 period (total and average by year are also presented).

YEAR	SUBDIVISION AND UNIT AREAS							
	3Pn	4Ra	4Rb	4Rc	4Rd	N.D.*	TOTAL	AVERAGE
1965	0	0	565	0	0	0	565	94
1966	0	0	300	48	250	0	598	100
1967	0	50	1086	78	182	0	1396	233
1968	0	0	400	26	324	0	750	125
1969	0	0	546	0	50	100	696	116
1970	0	348	500	0	200	50	1098	183
1971	0	250	700	300	150	650	2050	342
1972	0	550	1826	247	450	1222	4295	716
1973	0	1189	1885	436	546	200	4256	709
1974	0	1075	400	50	799	0	2324	387
1975	0	247	250	0	650	0	1147	191
1976	0	950	100	169	1219	0	2438	406
1977	0	1785	340	695	1440	450	4710	785
1978	0	2324	470	94	821	200	3909	652
1979	0	1350	450	873	1319	199	4191	699
1980	0	2597	799	1882	1099	0	6377	1063
1981	0	896	1376	1894	1200	0	5366	894
1982	0	150	686	984	259	0	2079	347
1983	0	1068	1226	1261	56	136	3747	625
1984	50	2064	3615	789	101	67	6686	1114
1985	0	1049	3700	1869	599	14	7231	1205
1986	0	1382	1740	1334	1288	31	5775	963
1987	0	1585	1132	1293	845	0	4855	809
1988	0	1697	1374	1260	1882	1	6214	1036
1989	0	928	1077	1420	998	7	4430	738
1990	0	1030	700	713	838	1	3282	547
1991	0	640	550	598	596	1	2385	398
1992	0	547	1029	678	697	5	2956	493
1993	0	1099	455	521	1228	2	3305	551
1994	0	1653	1155	1735	1200	0	5743	957
1995	0	1860	510	1735	1315	1	5421	904
1996	0	1859	400	1395	948	1	4603	767
1997	0	933	350	1178	1201	0	3662	610
1998	0	1149	300	447	586	1	2483	414
1999	0	600	297	822	847	1	2567	428
2000	0	600	600	728	749	1	2678	446
2001	0	600	50	495	449	1	1595	266
TOTAL	50	36104	32939	28047	27381	3342	127863	
AVERAGE	1	976	890	758	740	90	3456	

* Not Determined

Table 3. Mean length (mm) at age for the spring and fall spawning herring in NAFO Division 4R for different periods of time (data fitted according to the von Bertalanffy growth model).

	SPRING SPAWNERS					
AGE	1965-69	1970-79	1980-89	1990-99	2000-01	ALL
1	234.34	228.13	249.30			242.75
2	261.68	254.88	272.38	259.94	269.05	266.05
3	283.99	277.40	292.30	279.15	283.11	286.19
4	302.19	296.36	309.50	296.50	296.54	303.60
5	317.04	312.32	324.34	312.18	309.37	318.65
6	329.16	325.76	337.16	326.35	321.62	331.65
7	339.04	337.08	348.22	339.16	333.31	342.89
8	347.11	346.60	357.77	350.73	344.48	352.61
9	353.69	354.62	366.02	361.19	355.15	361.00
10	359.07	361.37	373.13	370.64	365.33	368.26
11	363.45	367.05	379.28	379.18	375.05	374.53
12				386.90		

	FALL SPAWNERS					
AGE	1965-69	1970-79	1980-89	1990-99	2000-01	ALL
2	266.35	264.36	274.64	243.04	239.33	263.03
3	280.95	282.30	291.97	265.11	260.92	282.01
4	294.71	298.85	308.07	285.21	280.33	299.37
5	307.67	314.11	323.04	303.51	297.77	315.24
6	319.88	328.19	336.95	320.18	313.46	329.75
7	331.38	341.17	349.87	335.36	327.55	343.01
8	342.22	353.15	361.88	349.19	340.22	355.14
9	352.43	364.19	373.04	361.78	351.61	366.23
10	362.06	374.38	383.41	373.24	361.85	376.37
11	371.12	383.77	393.05	383.68	371.06	385.64
12	379.66	392.44	402.01	393.19	379.33	394.11

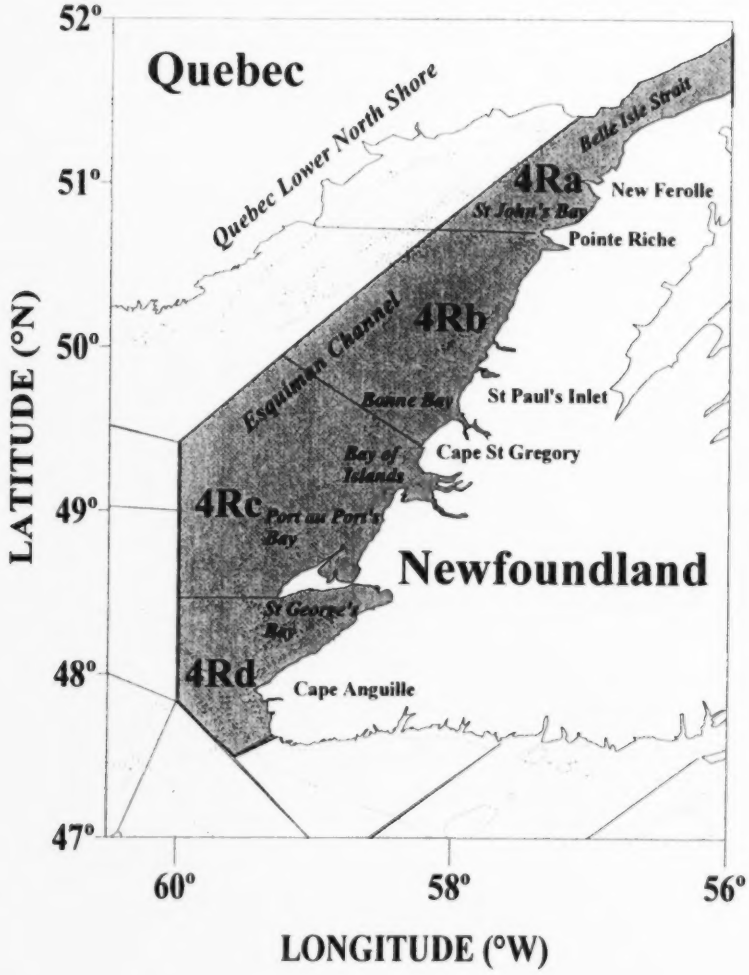


Figure 1. Map of the unit areas of NAFO Division 4R on the west coast of Newfoundland (Division 4R is indicated by the shaded area).

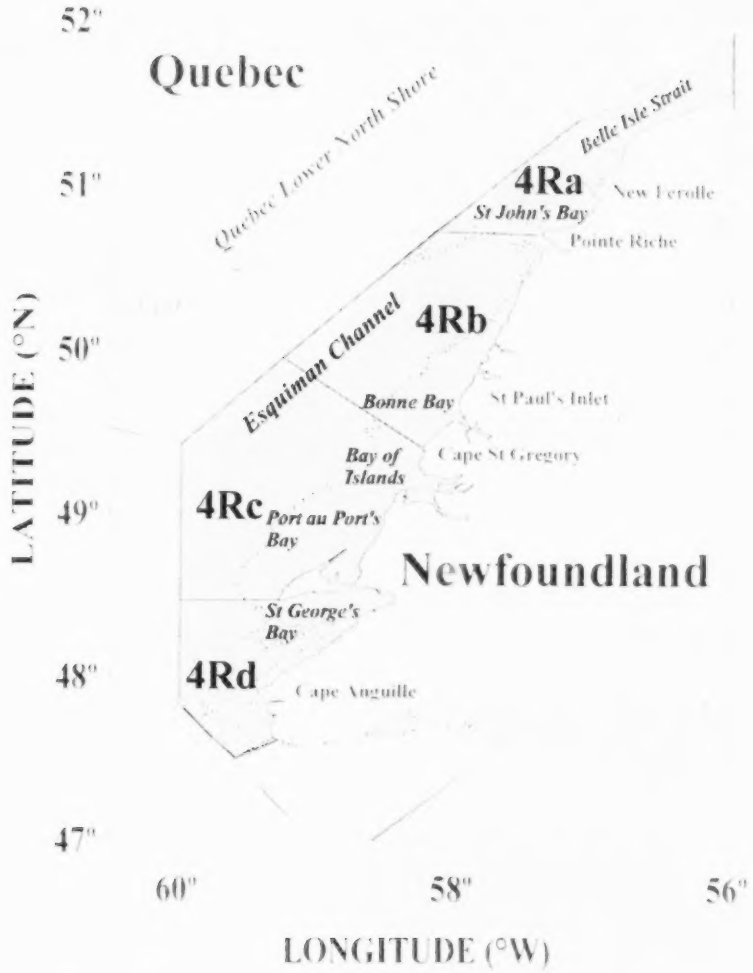


Figure 1. Map of the unit areas of NAFO Division 4R on the west coast of Newfoundland (Division 4R is indicated by the shaded area).

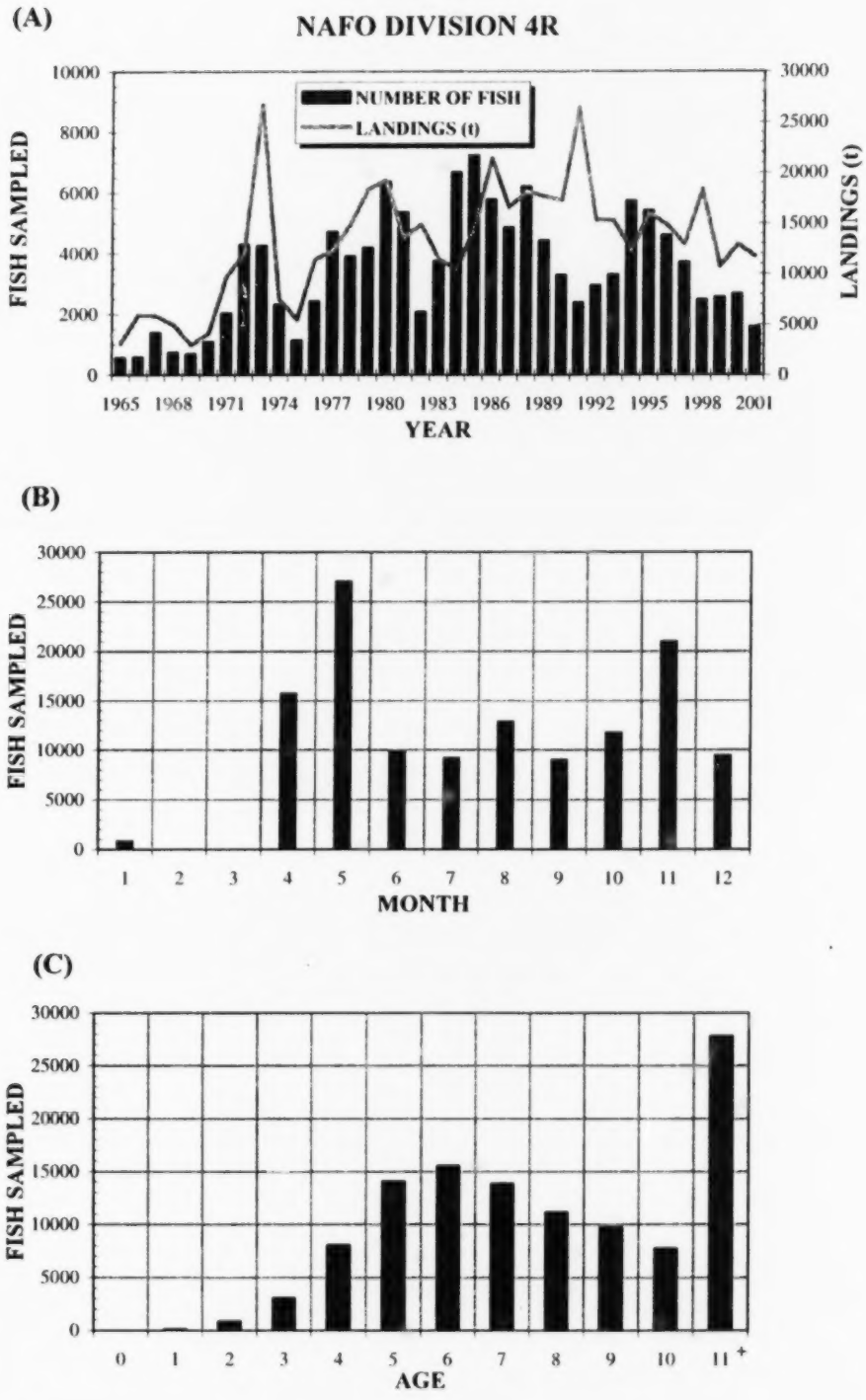


Figure 2. Landings (t) and number of herring sampled in NAFO Division 4R (A), grouped by month (B), and age (C) for the 1965-2001 period (age group 11^{+} represents all fish 11 years of age or over).

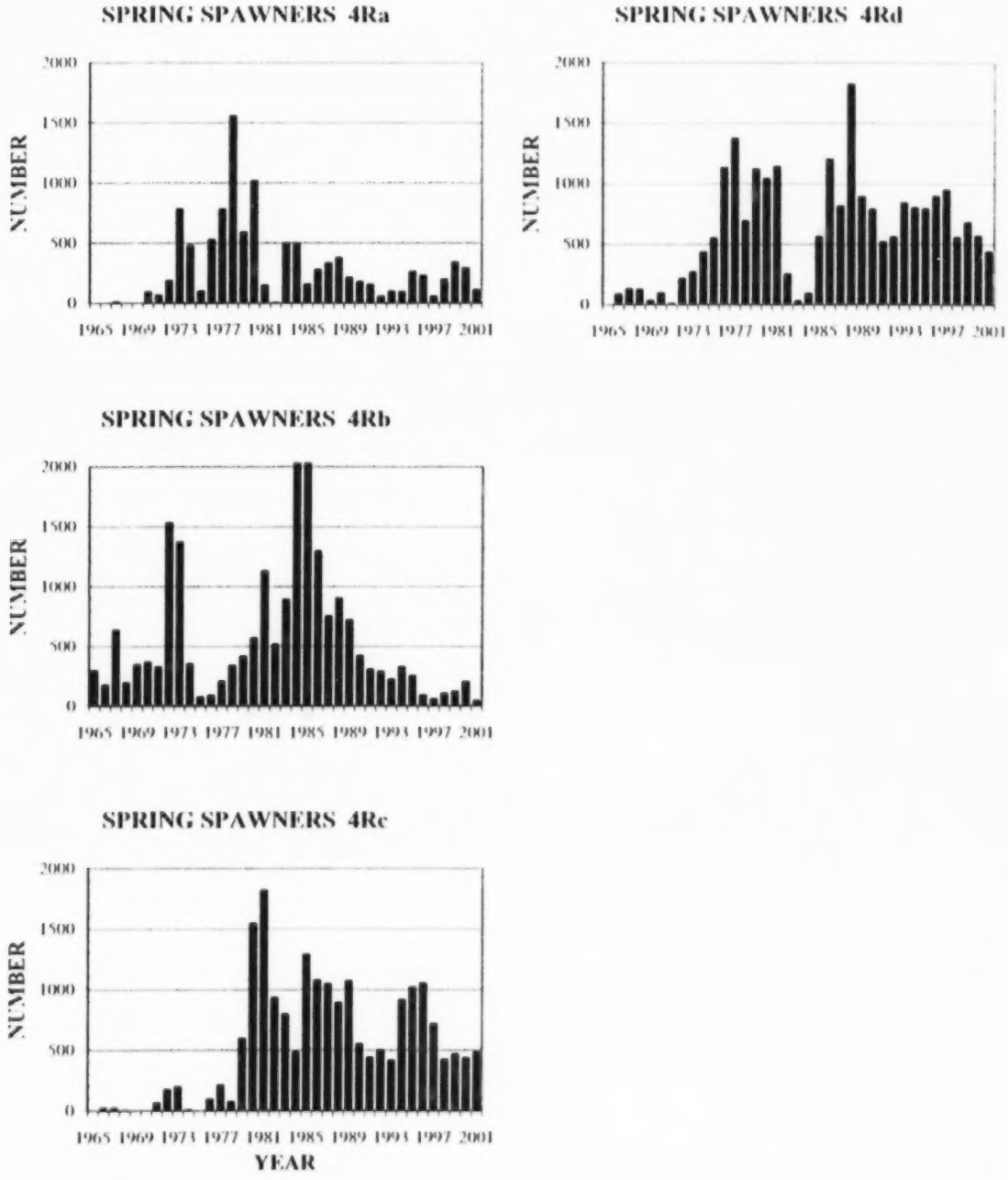


Figure 3. Number of herring sampled by year, unit area, and spawning group for the 1965-2001 period.

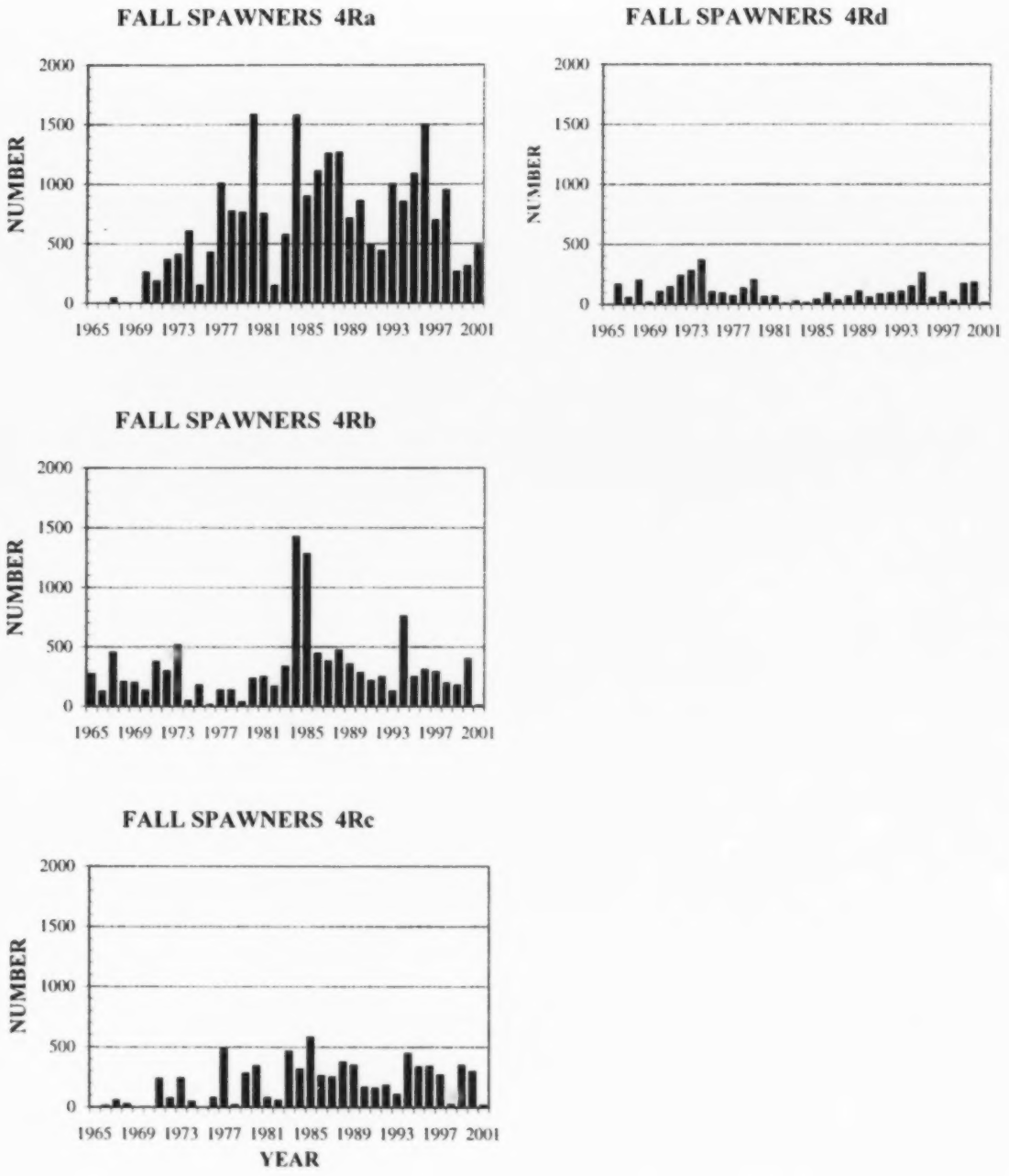


Figure 3. (Continued).

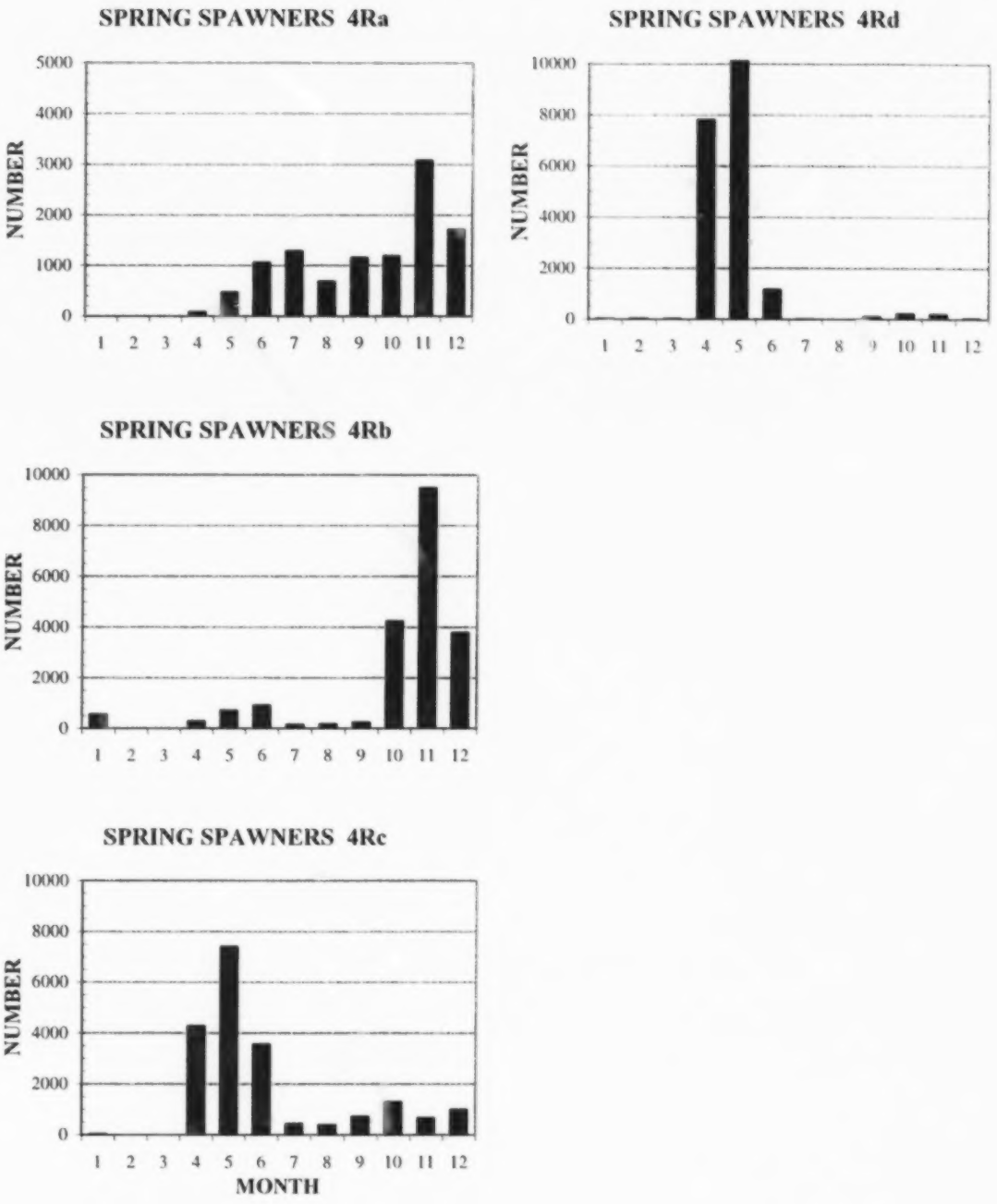


Figure 4. Number of herring sampled by month, unit area, and spawning group for the 1965-2001 period.

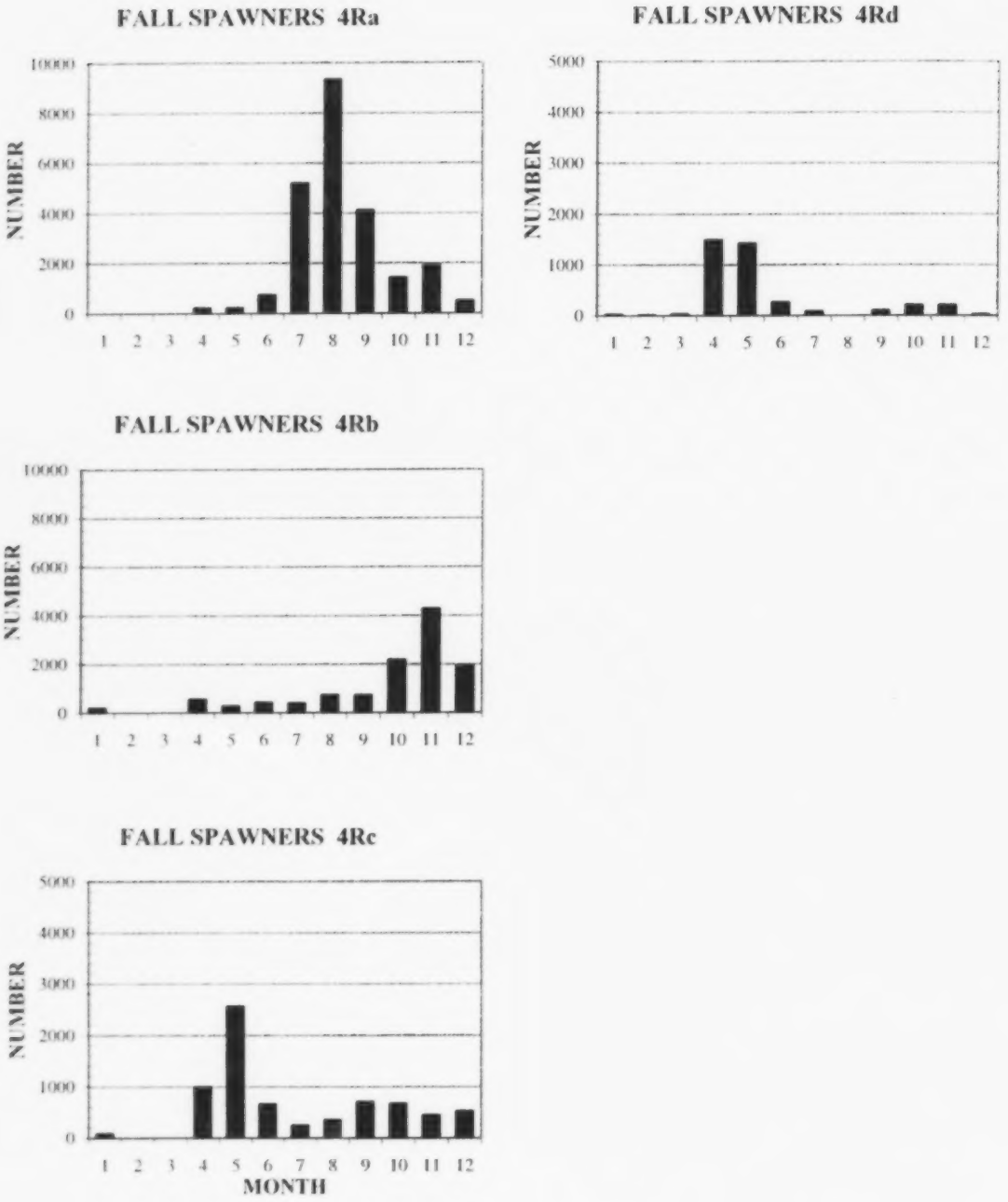


Figure 4. (Continued).

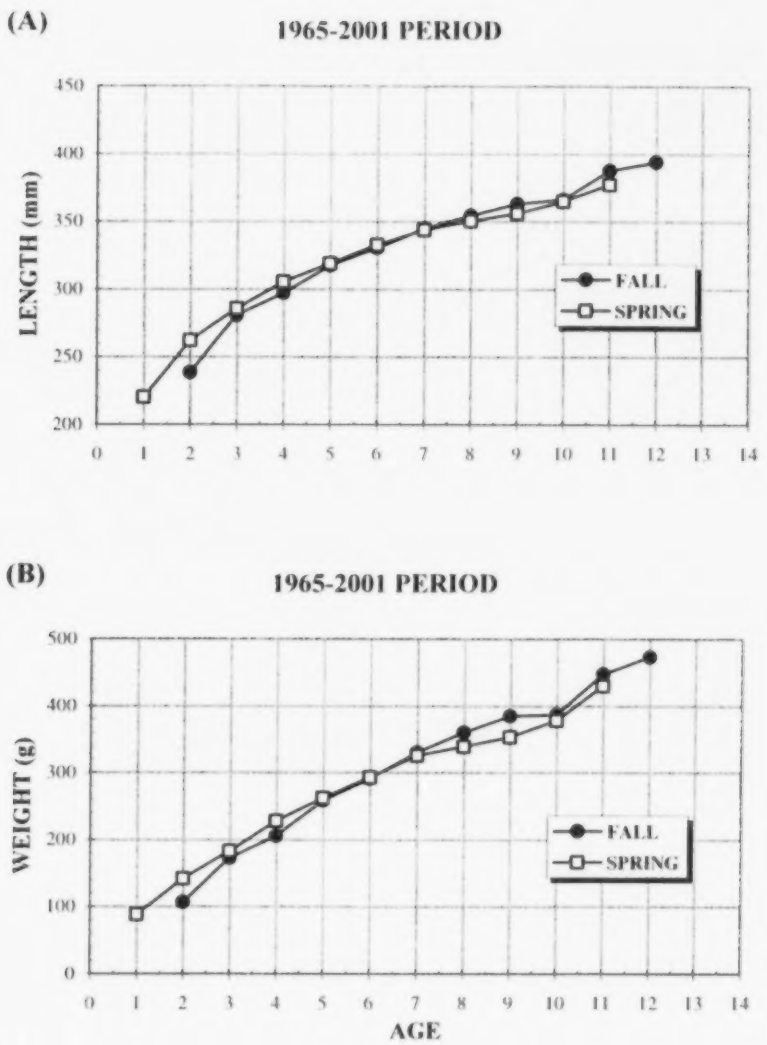
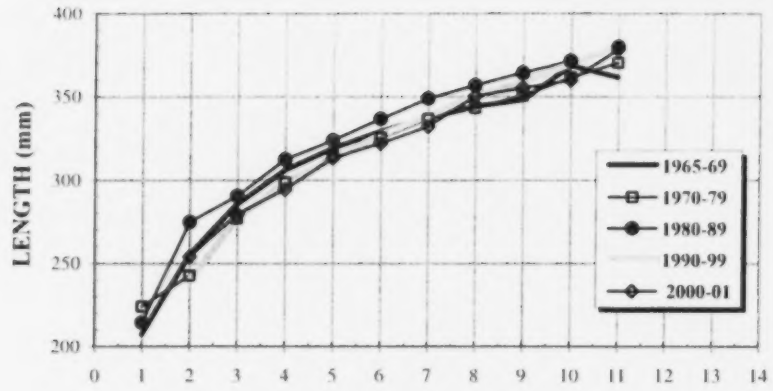


Figure 5. Mean length (mm) (A) and weight (g) (B) at age for spring and fall spawning herring sampled in NAFO Division 4R between 1965 and 2001.

(A)



(B)

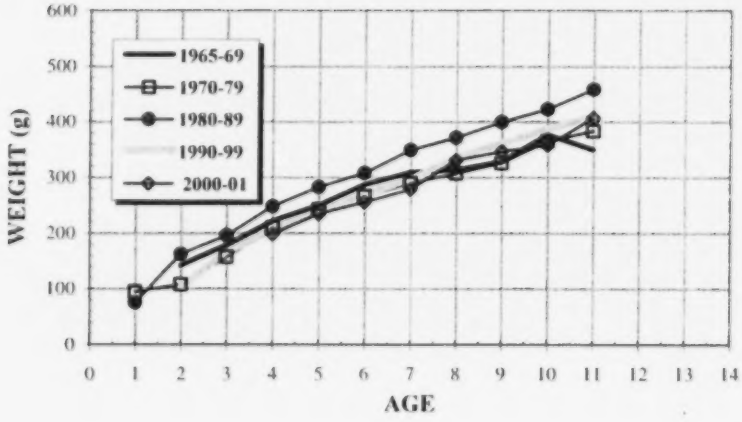


Figure 6. Mean length (mm) (A) and weight (g) (B) at age for spring spawning herring in NAFO Division 4R for different periods of time.

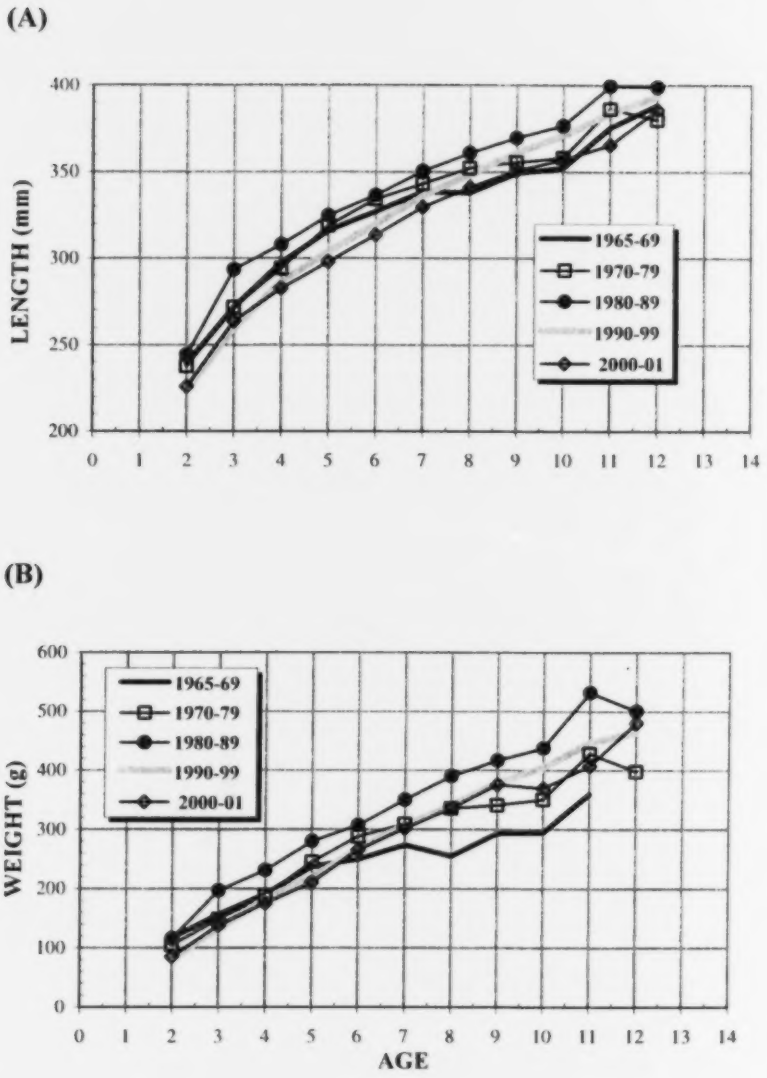


Figure 7. Mean length (mm) (A) and weight (g) (B) at age for fall spawning herring in NAFO Division 4R for different periods of time.

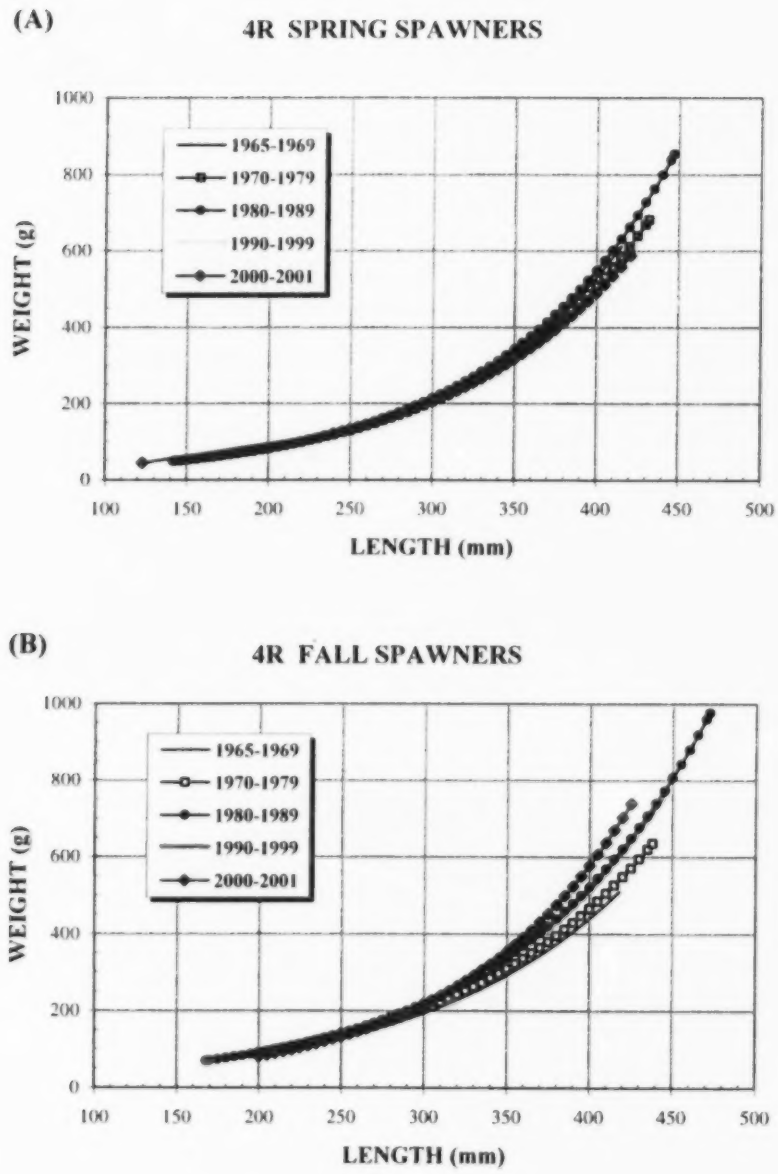


Figure 8. Weight-length relationships calculated for spring (A) and fall (B) spawning herring in NAFO Division 4R for different periods of time.

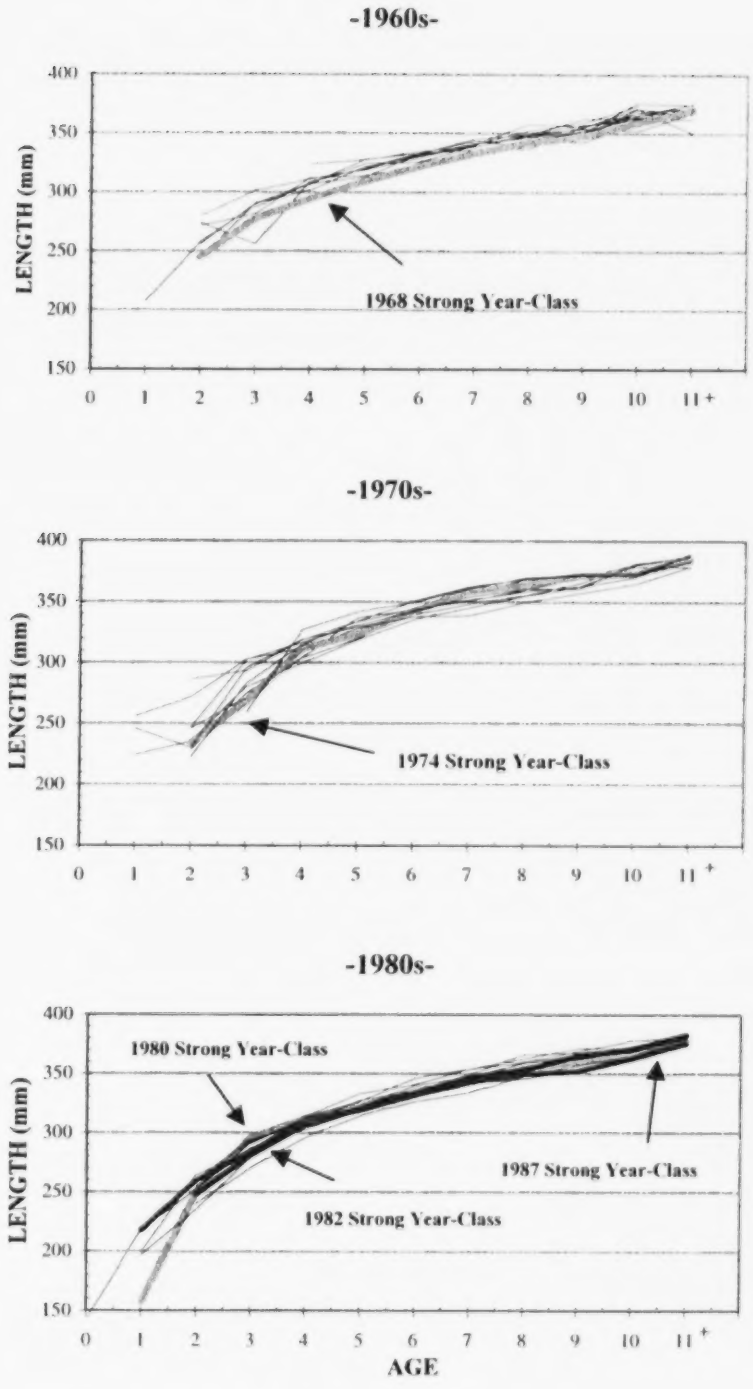


Figure 9. Mean length (mm) at age by year-class for spring spawning herring sampled in NAFO Division 4R since 1965 (the largest year-classes that have dominated the fishery are also indicated).

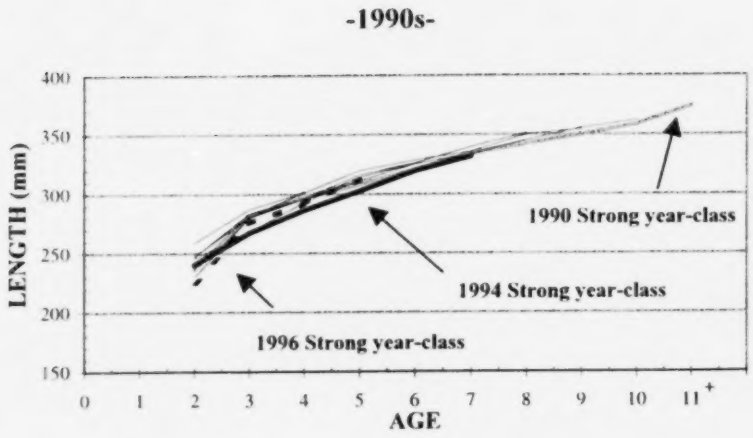


Figure 9. (Continued).

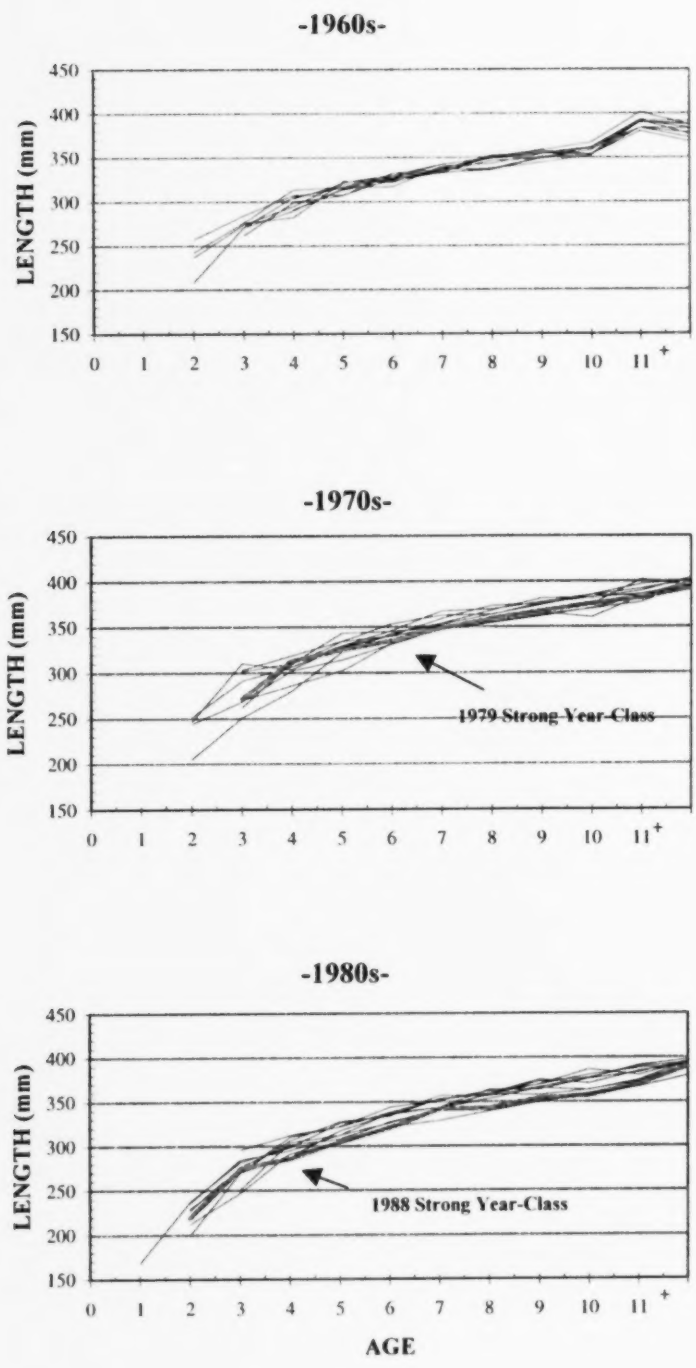


Figure 10. Mean length (mm) at age by year-class for fall spawning herring sampled in NAFO Division 4R since 1965 (the largest year-classes that have dominated the fishery are also indicated).

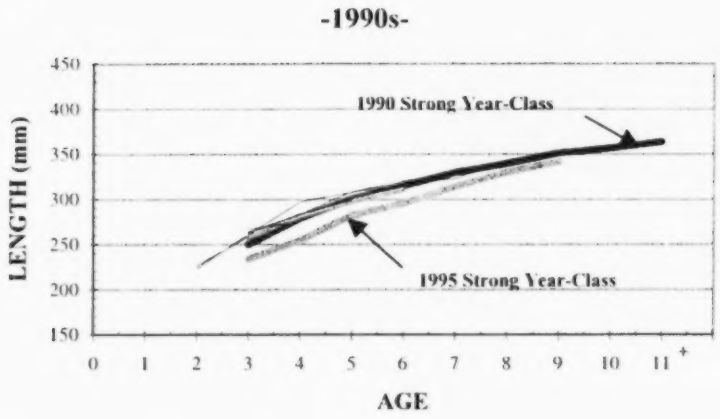


Figure 10. (Continued).

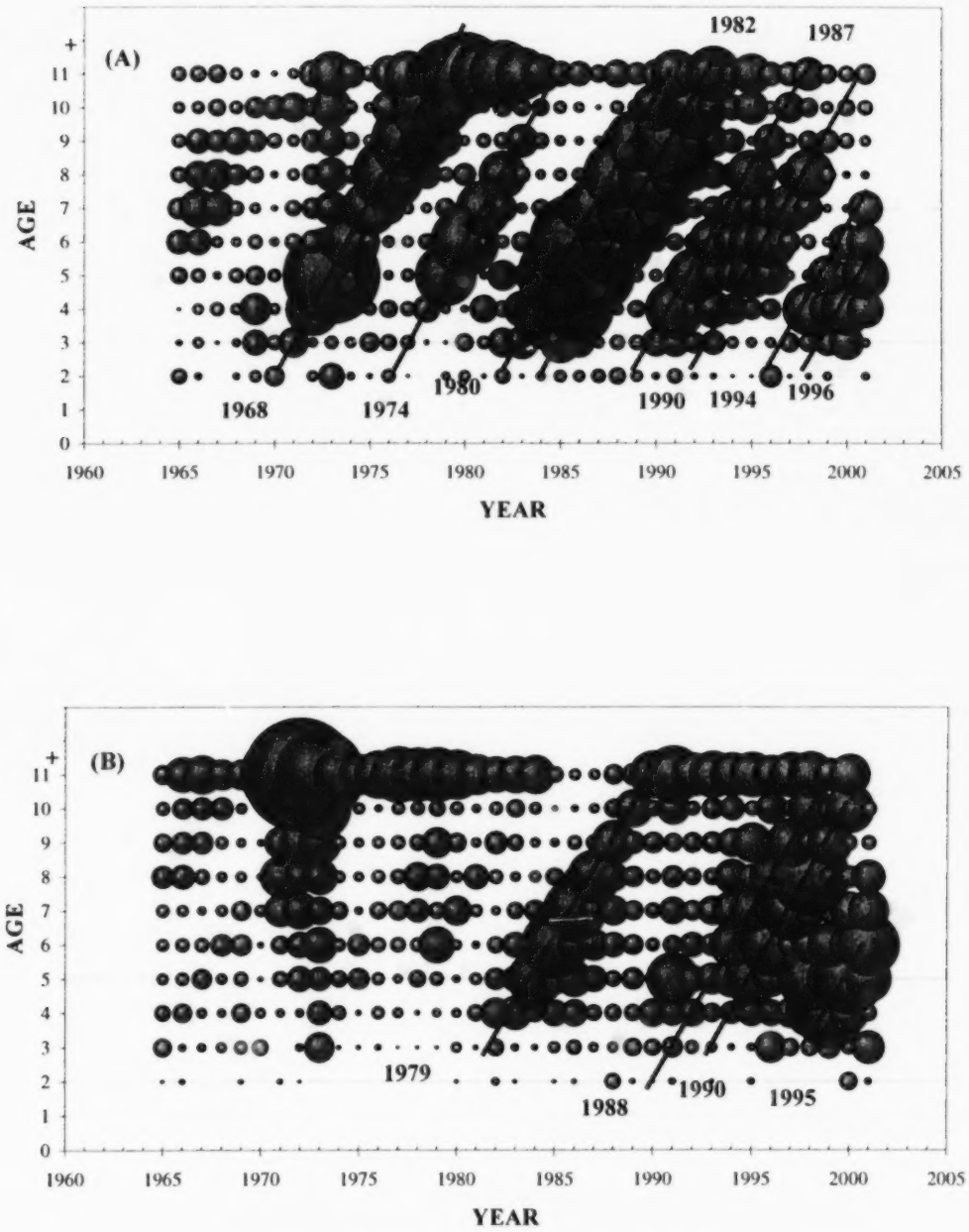


Figure 11. Catch at age (%) of spring (A) and fall (B) spawning herring for the year-classes sampled in NAFO Division 4R since 1965 (strong year-classes are also shown; age group 11^{+} represents all fish 11 years of age or over).

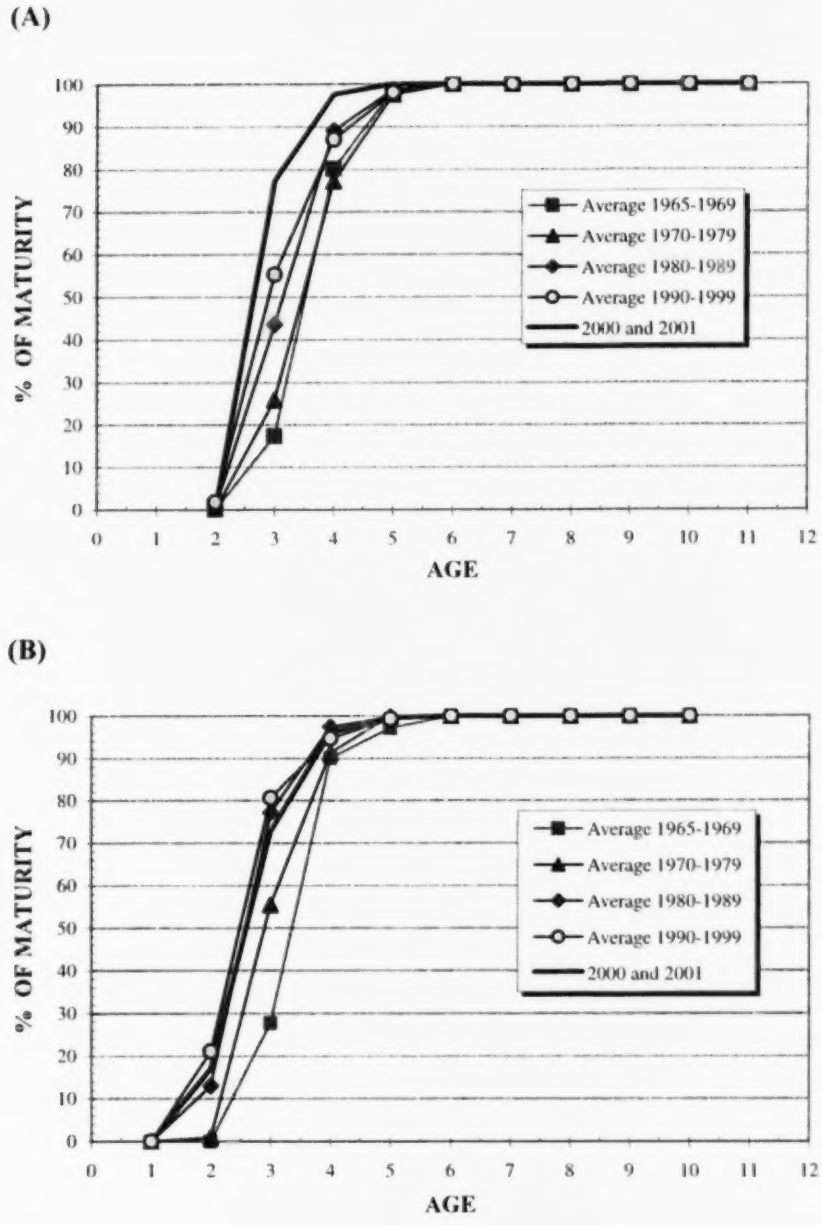


Figure 12. Mean maturity percentages at age for spring (A) and fall (B) spawning herring sampled in NAFO Division 4R since 1965 and grouped by different periods of time.

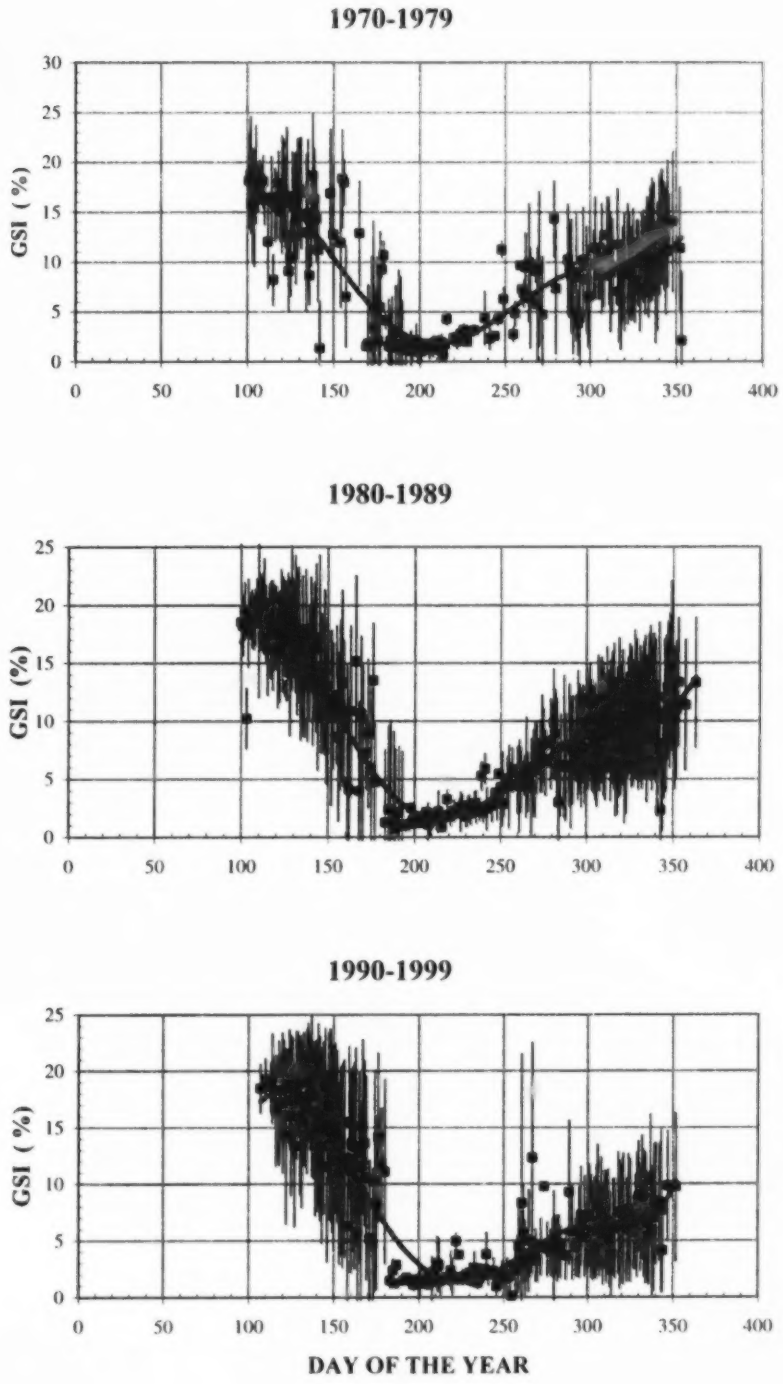
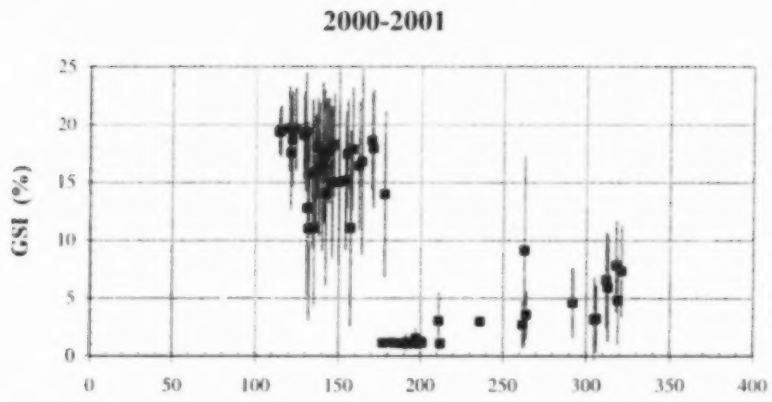


Figure 13. Mean daily values, standard deviations, and fitted values of the gonadosomatic index for spring spawning herring sampled in NAFO Division 4R since 1970 (data were fitted with a polynomial model except in 2000-2001 where their numbers were insufficient).



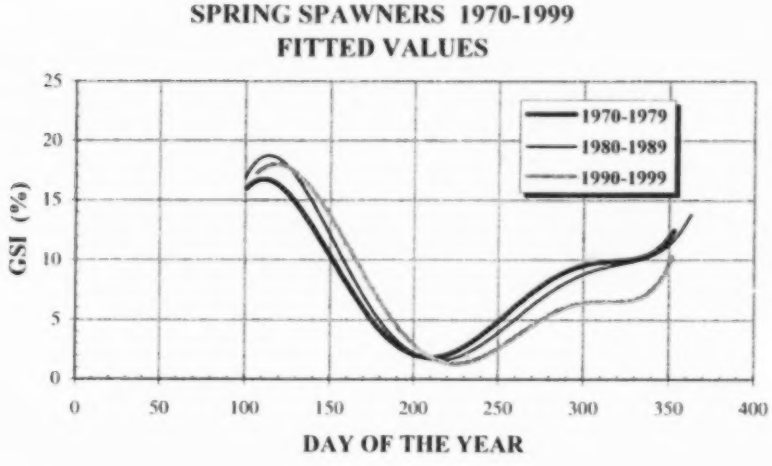


Figure 13. (Continued).

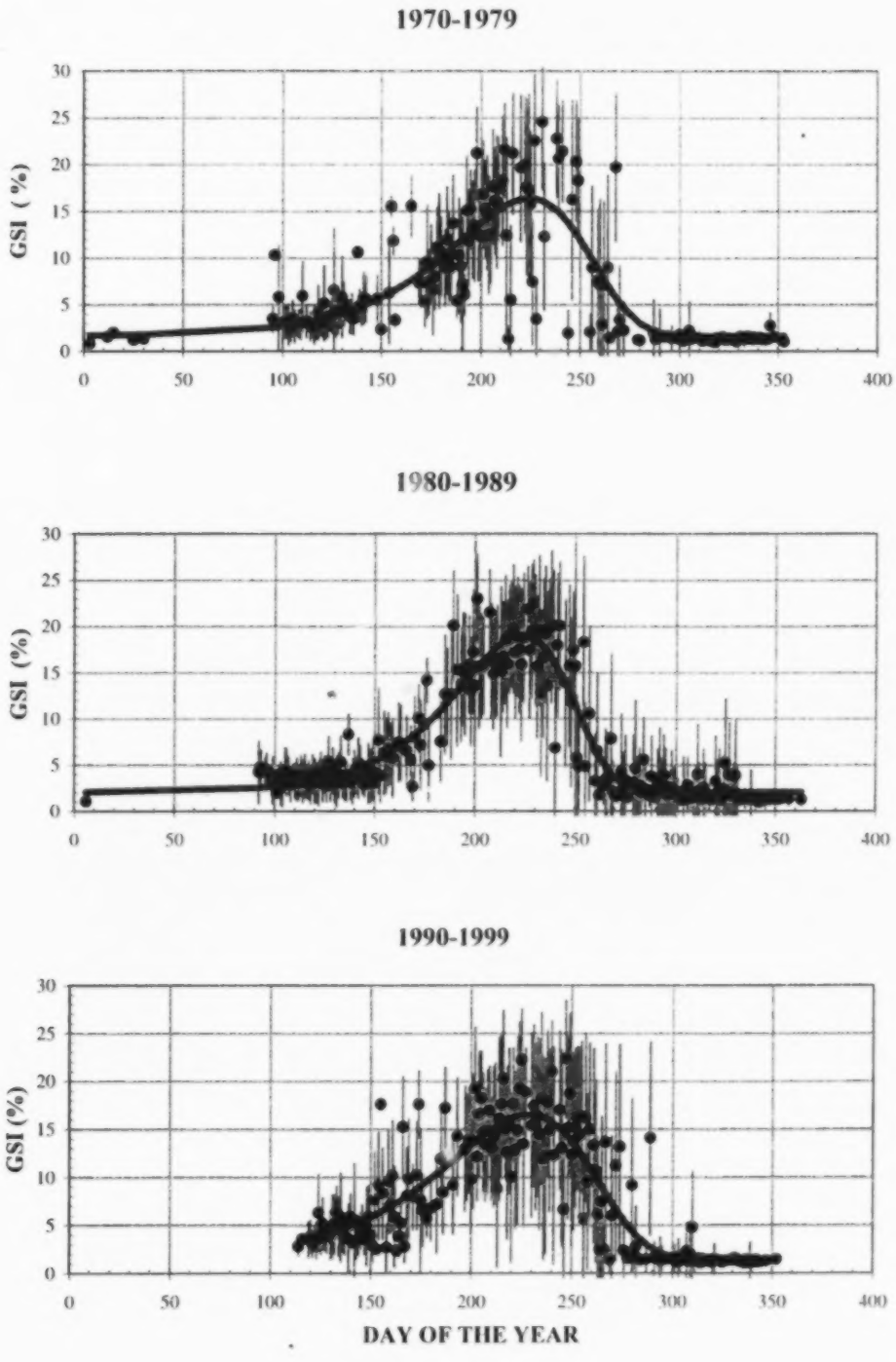
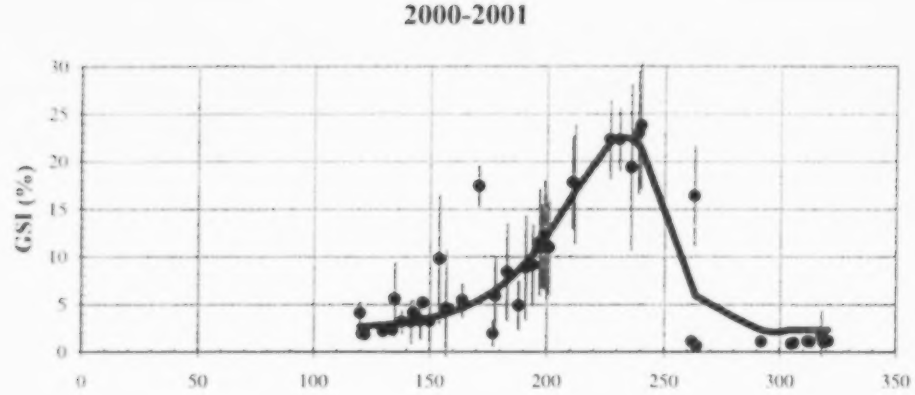


Figure 14. Mean daily values, standard deviations, and fitted values of the gonadosomatic index for fall spawning herring sampled in NAFO Division 4R since 1970 (data were fitted with a modified Weibull model).



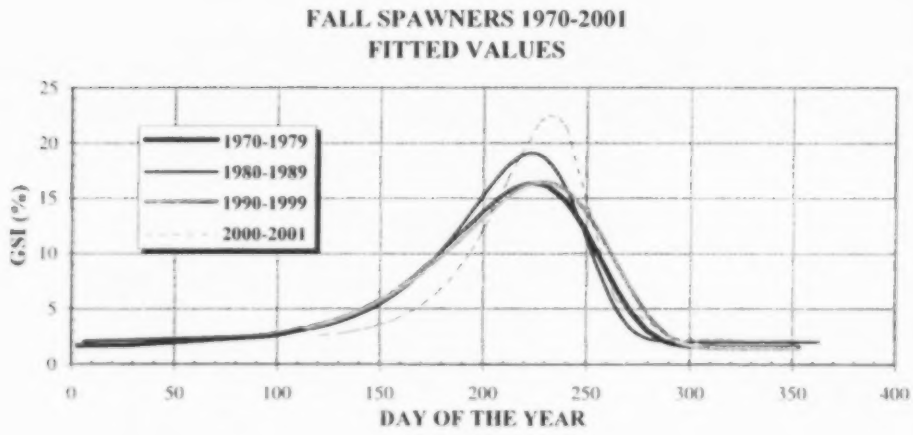


Figure 14. (Continued).

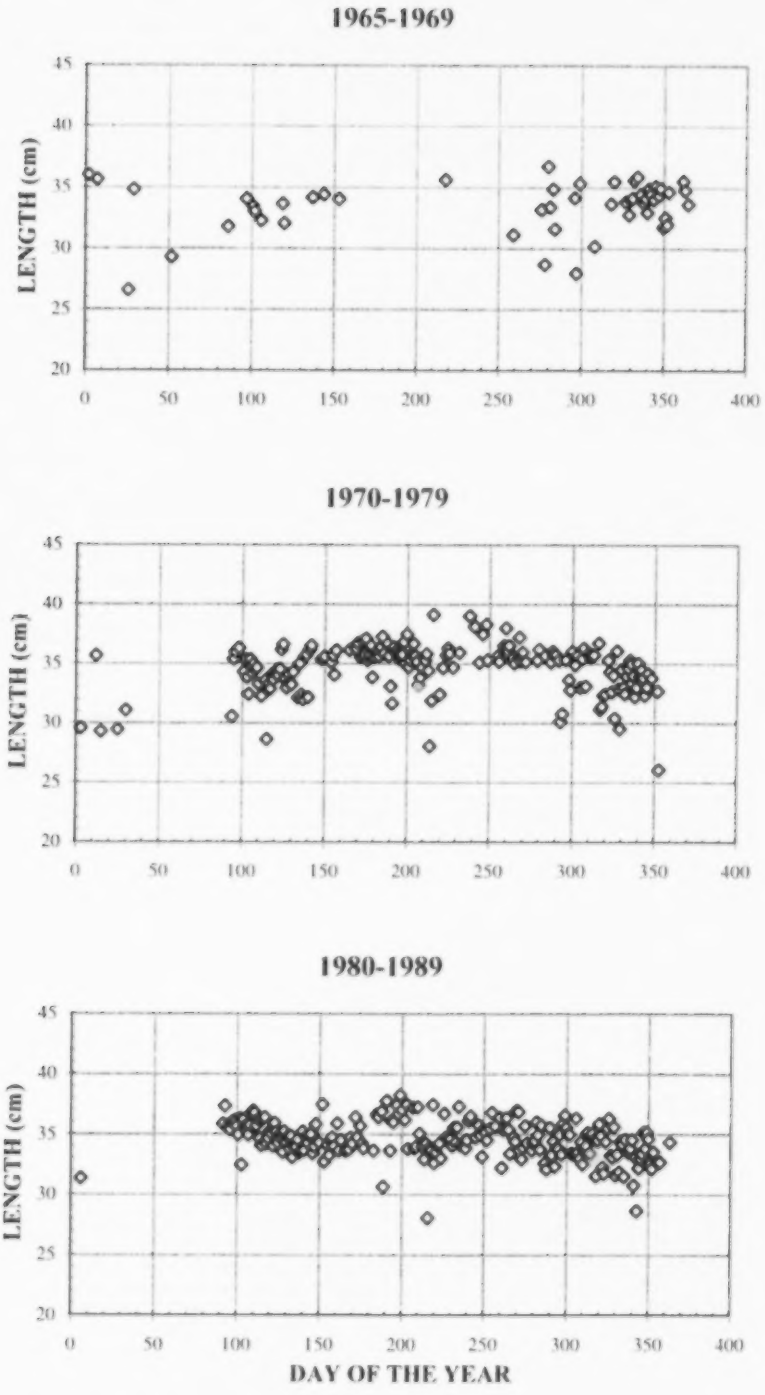


Figure 15. Mean daily length (cm) values of spring spawning herring sampled in NAFO Division 4R since 1965 and grouped by different periods of time.

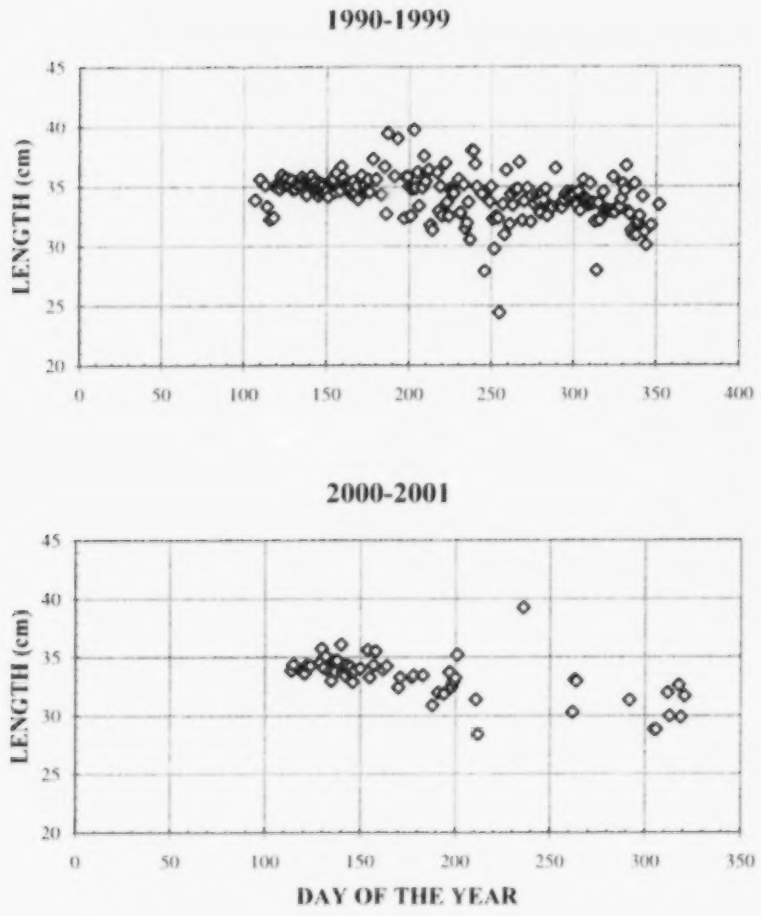


Figure 15. (Continued).

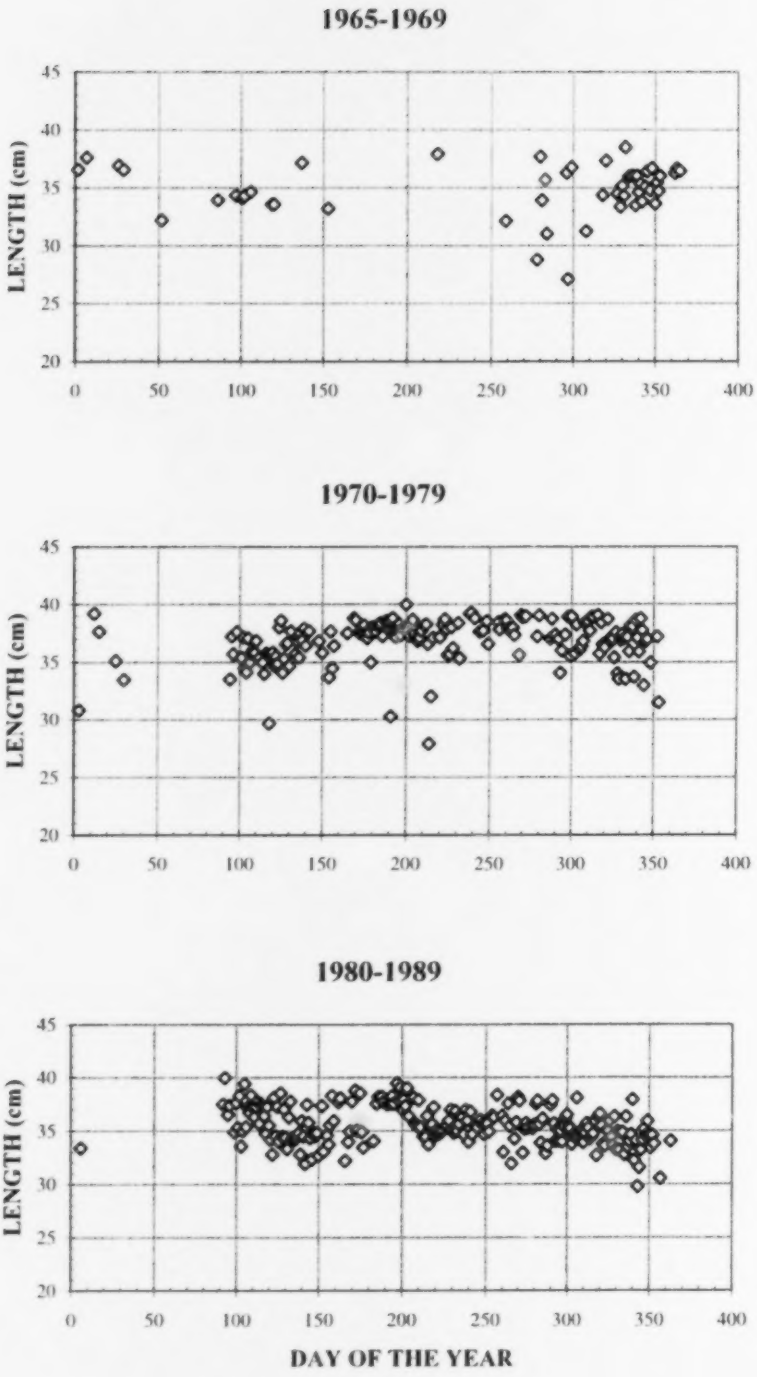


Figure 16. Mean daily length (cm) values of fall spawning herring sampled in NAFO Division 4R since 1965 and grouped by different periods of time.

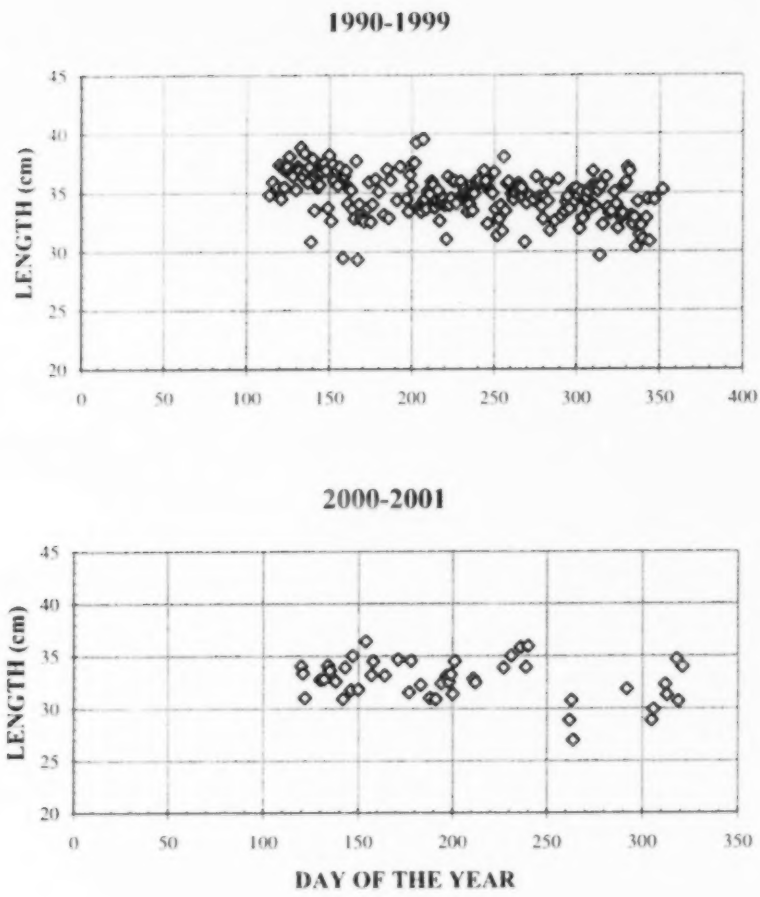


Figure 16. (Continued).

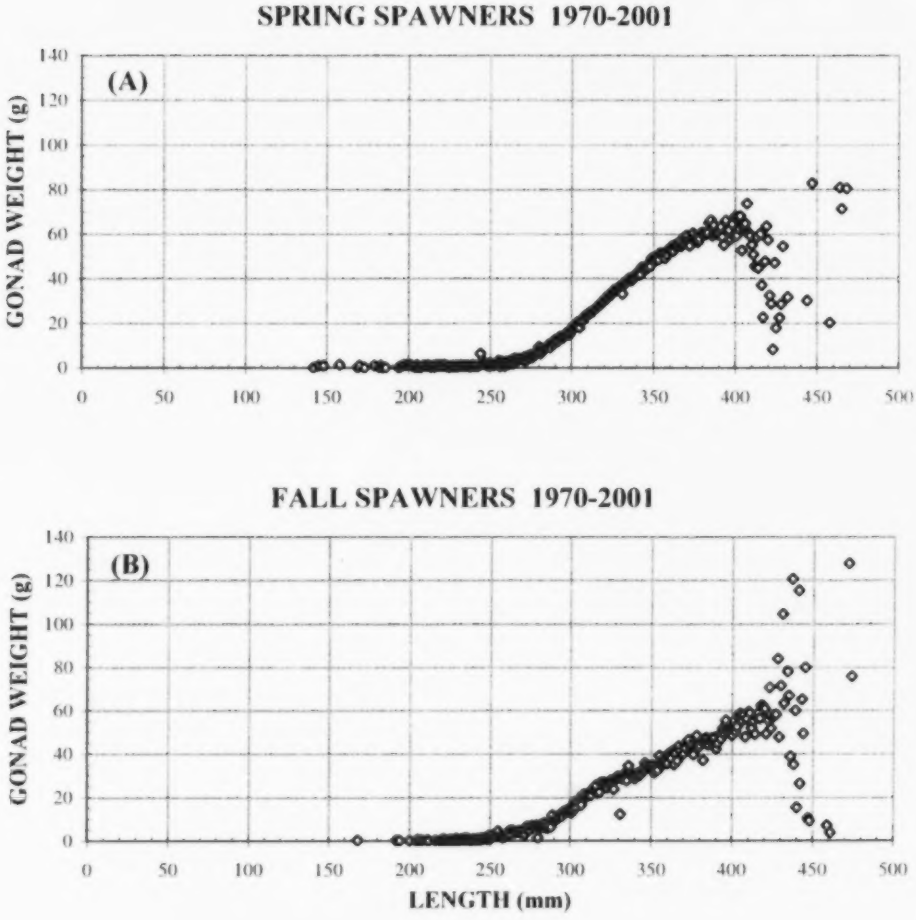
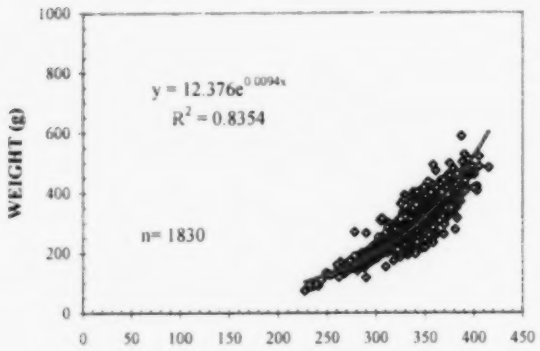


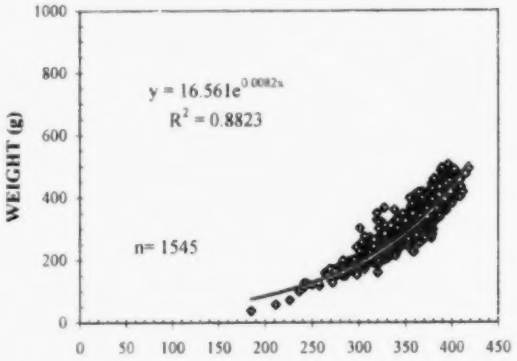
Figure 17. Mean gonad weight (g) by length (mm) for spring (A) and fall (B) spawning herring sampled in NAFO Division 4R since 1970.

Appendix 1. Weight–length relationships for spring and fall spawning herring of NAFO Division 4R for different periods of time.

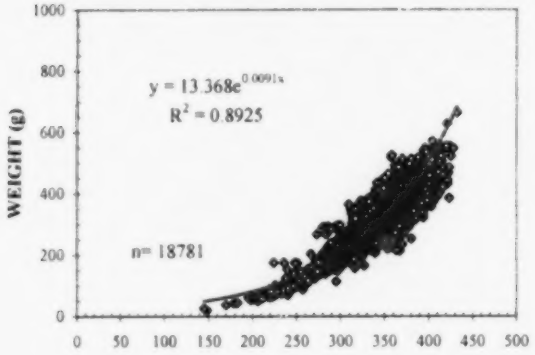
SPRING SPAWNERS 1965-1969



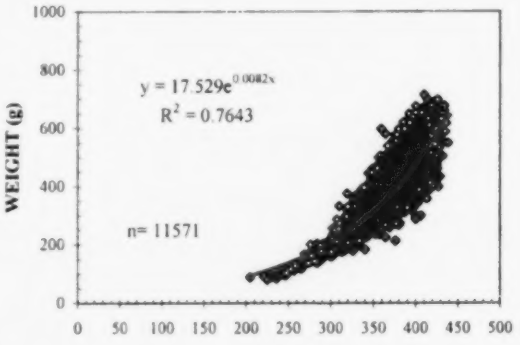
FALL SPAWNERS 1965-1969



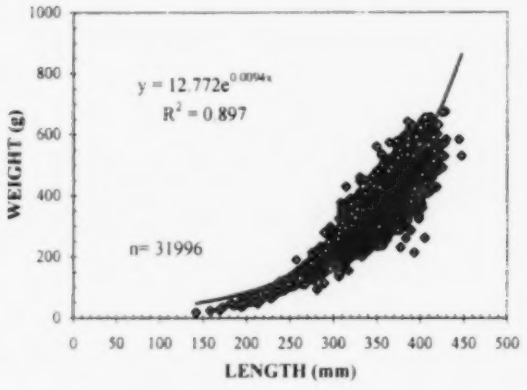
SPRING SPAWNERS 1970-1979



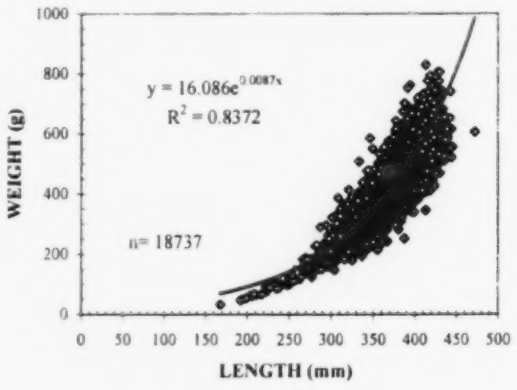
FALL SPAWNERS 1970-1979



SPRING SPAWNERS 1980-1989

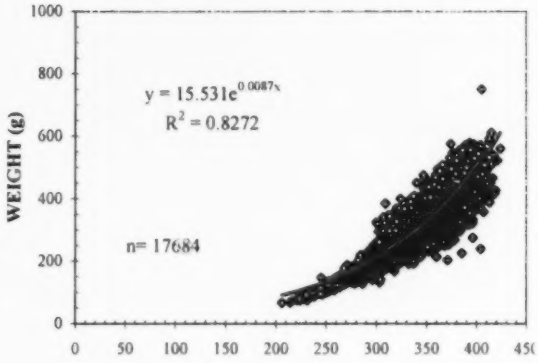


FALL SPAWNERS 1980-1989

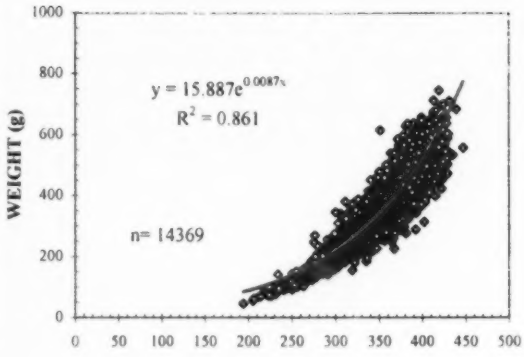


Appendix 1. (Continued).

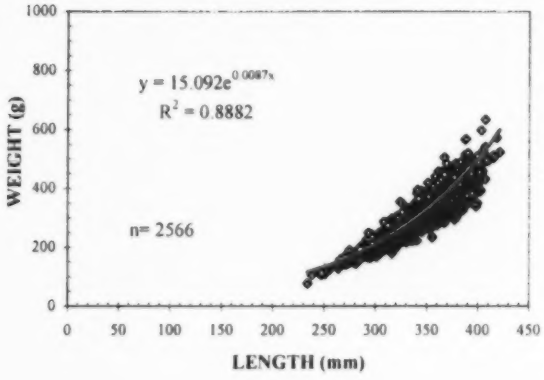
SPRING SPAWNERS 1990-1999



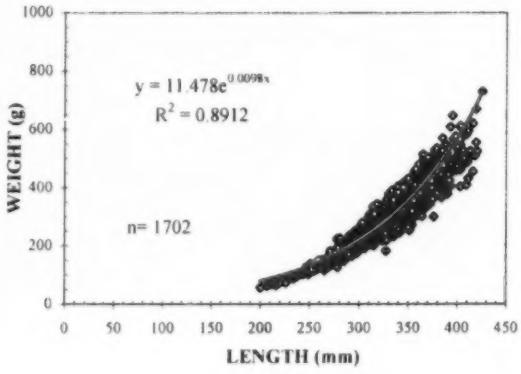
FALL SPAWNERS 1990-1999



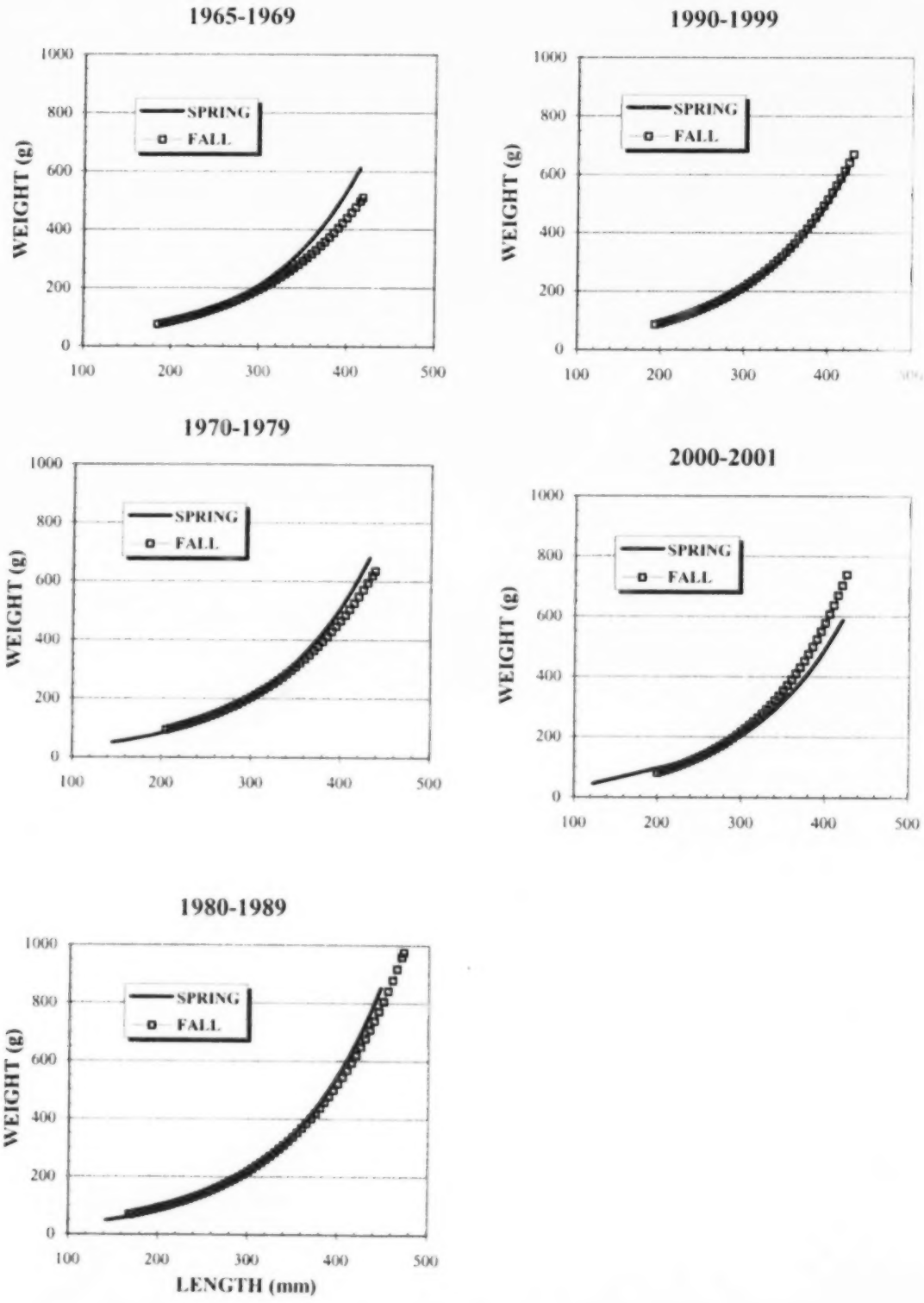
SPRING SPAWNERS 2000-2001



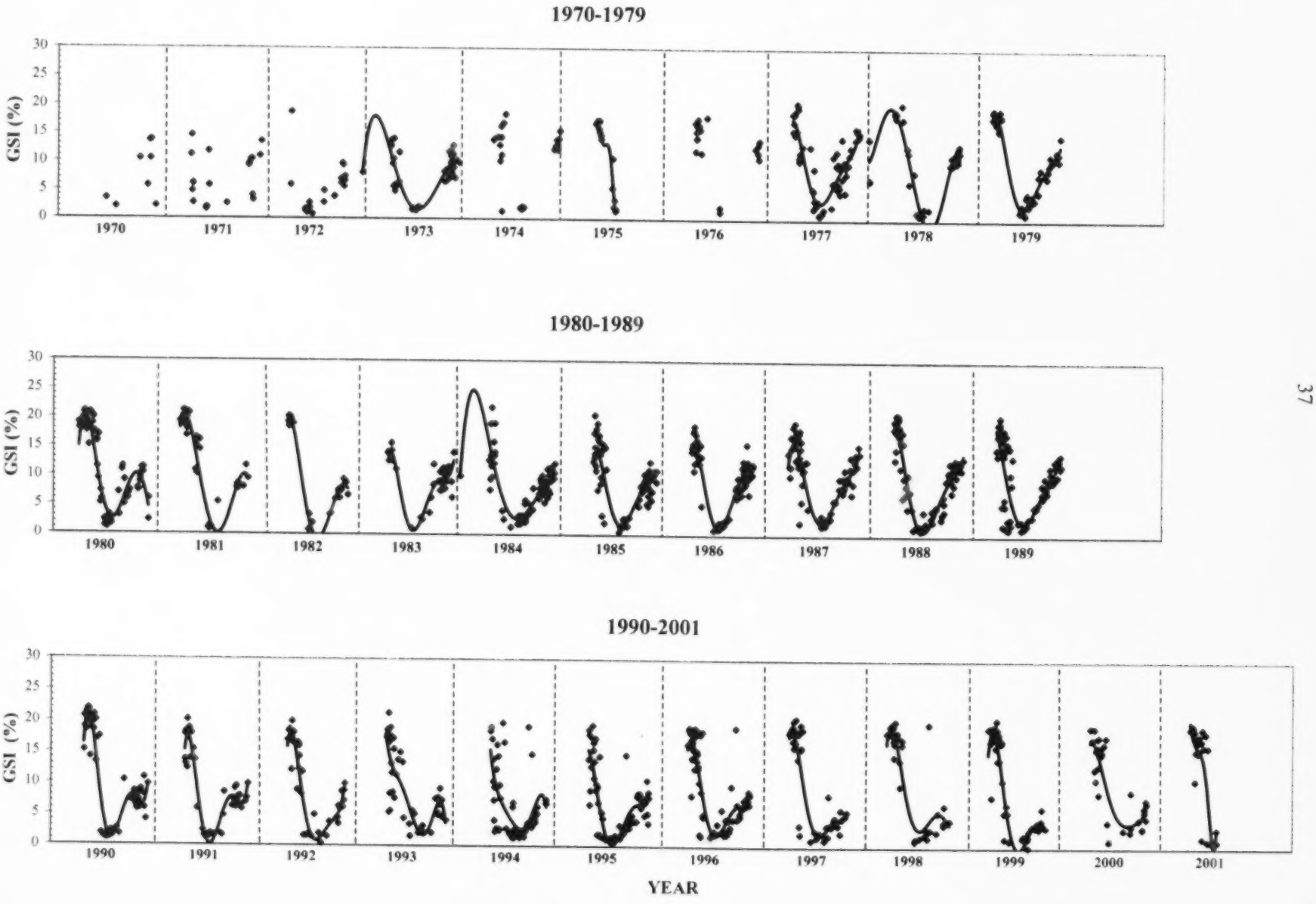
FALL SPAWNERS 2000-2001



Appendix 2. Comparisons by period of time of the fitted weight–length relationships for spring and fall spawning herring in NAFO Division 4R.



Appendix 3. Daily gonadosomatic index values (observed and fitted) for spring spawning herring in NAFO Division 4R for different periods of time.



Appendix 4. Daily gonadosomatic index values (observed and fitted) for fall spawning herring in NAFO Division 4R for different periods of time.